CORPS OF ENGINEERS, U. S. ARMY

MORGANZA FLOODWAY CONTROL STRUCTURE

MISSISSIPPI RIVER

HYDRAULIC MODEL INVESTIGATION

TECHNICAL MEMORANDUM NO. 2-326

WATERWAYS EXPERIMENT STATION

VICKSBURG, MISSISSIPPI

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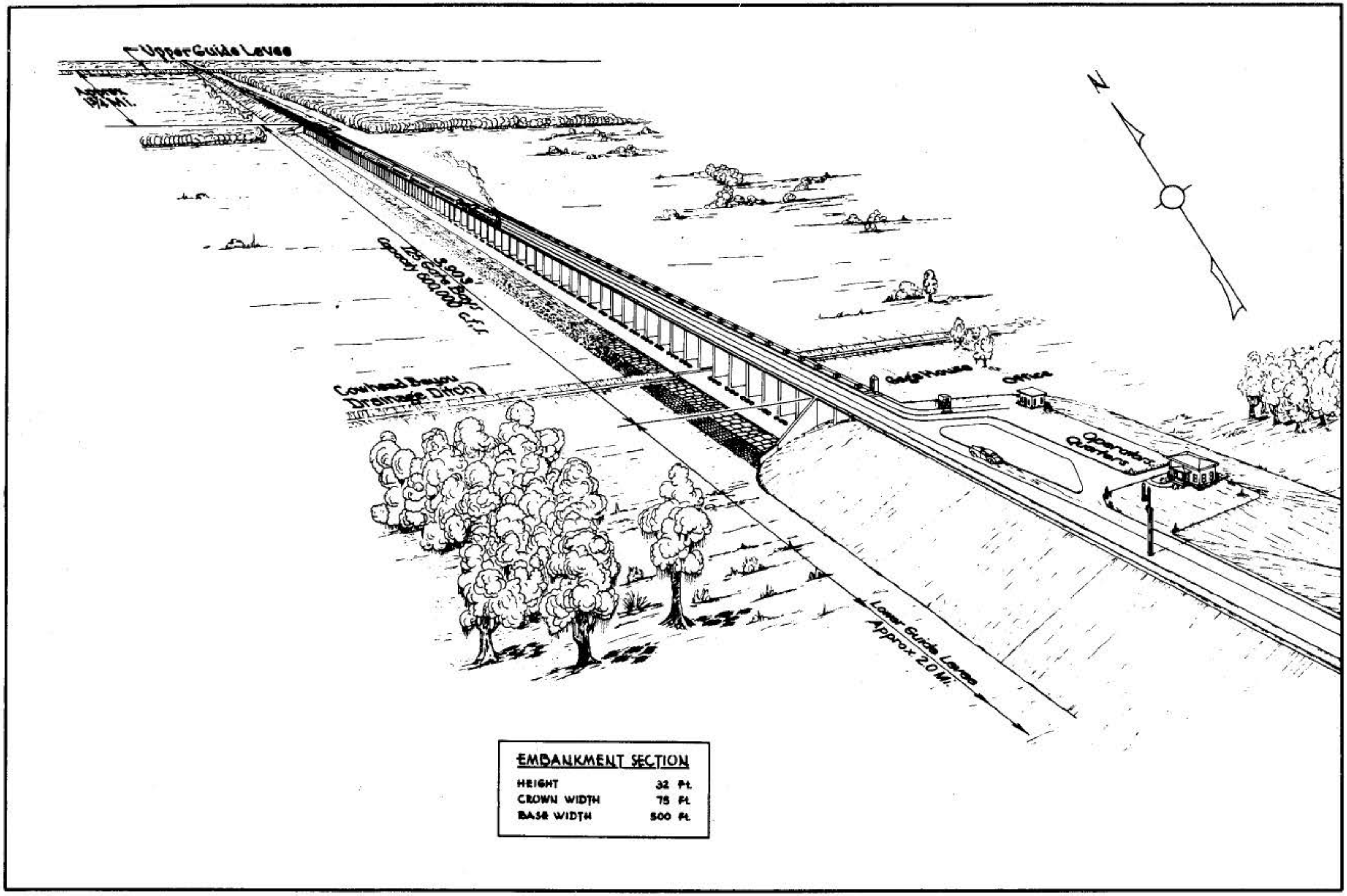

Frontispiece. Morganza floodway control structure

PREFACE

Authority to conduct model studies of the Morganza Floodway Control Structure was granted by the President, Mississippi River Commission, in a letter to the Director, Waterways Experiment Station, dated 2 August 1946, subject: "Model Tests of Morganza Floodway Control Structure." The model studies were accomplished during the period December 1946-July 1948 in the Hydraulics Division of the Waterways Experiment Station by Messrs. J. W. Bolin, Jr. and S. H. Halper, under the general supervision of Messrs. F. R. Brown and T. E. Murphy.

Messrs. E. J. Williams, J. E. Sanders, C. L. Sumrall, Jr., and F. B. Toffaleti, engineers of the Mississippi River Commission, visited the Waterways Experiment Station at frequent intervals during the course of the studies to discuss the testing program and to correlate test results with design work concurrently being accomplished.

CONTENTS

SUMMARY

Model investigations of the control structure for the Morganza Floodway were conducted to examine the over-all performance of the structure with particular attention to discharge coefficients, flow at the abutments, and energy dissipation. Three models were used in this study: a 1:16-scale model reproducing five gate bays and the right abutment of the structure as originally designed; a 1:30-scale section model reproducing two full and two half bays; and a 1:20-scale model reproducing five bays and the right abutment of a combined control-railway-highway structure.

Test results indicated the desirability of using a 5-ft-wide broad-crested weir; flared training walls extending above the maximum expected water surface at the abutments; and a horizontal apron supporting two rows of baffle piers and terminated by a 4-ft-high sloping end sill.

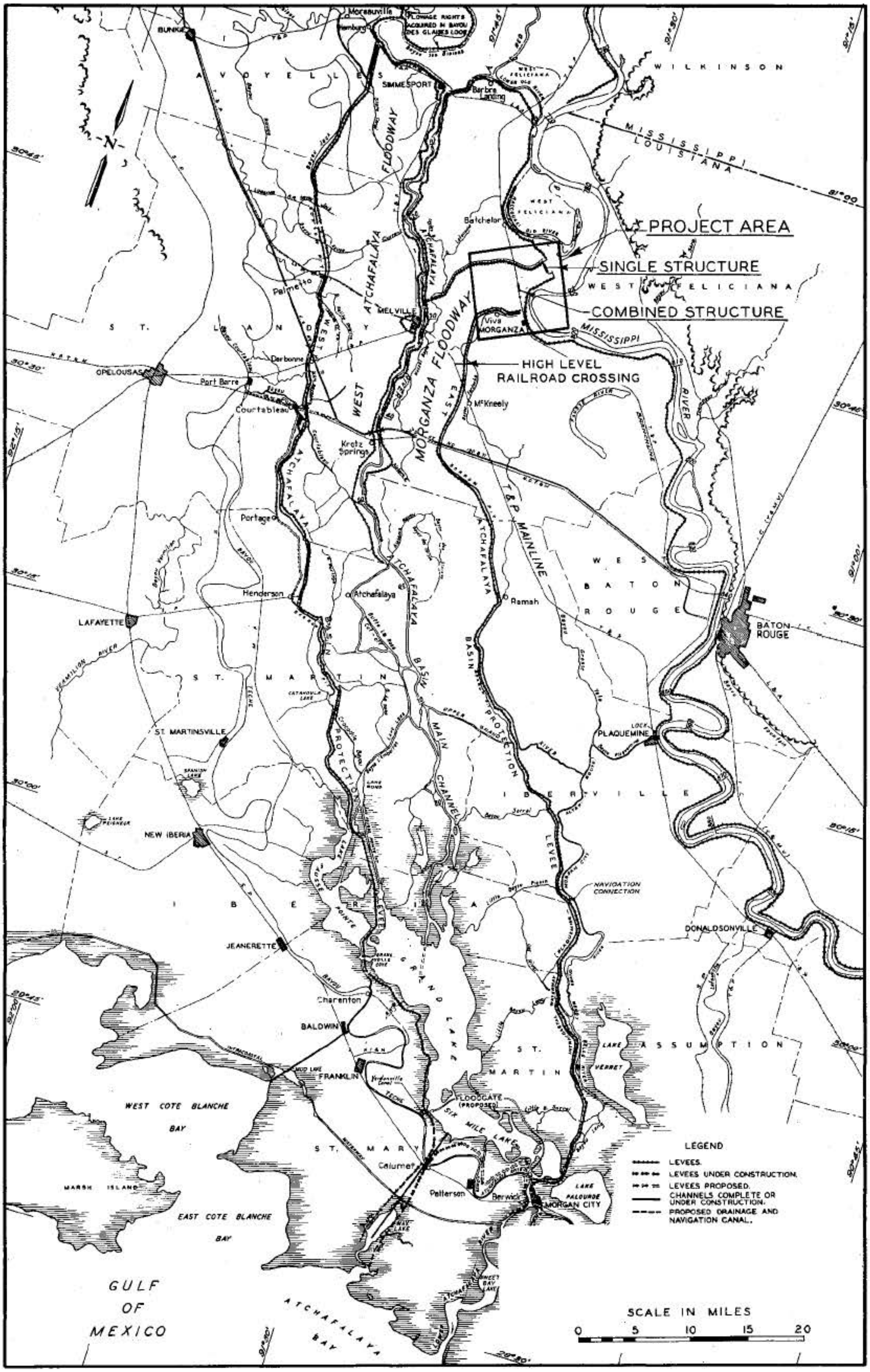

Fig. 1. Vicinity map

MORGANZA FLOODWAY CONTROL STRUCTURE, MISSISSIPPI RIVER

Hydraulic Model Investigation

PART I: INTRODUCTION

Pertinent Features of the Prototype

1. The Morganza Floodway, located on the west side of the Mississippi River about 40 miles above Baton Rouge, Louisiana, is a part of a vast flood protection system for the lower Mississippi Valley. The floodway is four to six miles wide and approximately 30 miles long, bounded by the Atchafalaya River east levee on the west and the Atchafalaya Basin east protection levee on the east, with the main-line Mississippi River levee at its head (fig. 1). Operation of the floodway will divert a part of the Mississippi River flood waters into the lower Atchafalaya Basin, where they will merge with flows from the Atchafalaya River and West Atchafalaya Floodway. This combined flow will be carried by the lower Atchafalaya River and Wax Lake Outlet into the Gulf of Mexico.

2. Two plans for the control structure, which will regulate flow into the Morganza Floodway, were investigated during the course of the study reported herein. The plan studied initially embodied a Bonnet Carre type needle structure 4,773 ft long consisting of 191 bays, each 23 ft wide, separated by 2-ft-wide piers. Atop the piers was a narrow-gage railway which carried the equipment required to handle the needles.

A low ogee weir with its crest at elevation 44* supported the needles used in closing the bays and also constituted the flow-measuring element. A stilling basin, composed of an 80-ft-long horizontal apron on which were located two rows of baffle piers and an end sill, completed the structure (plate 1).

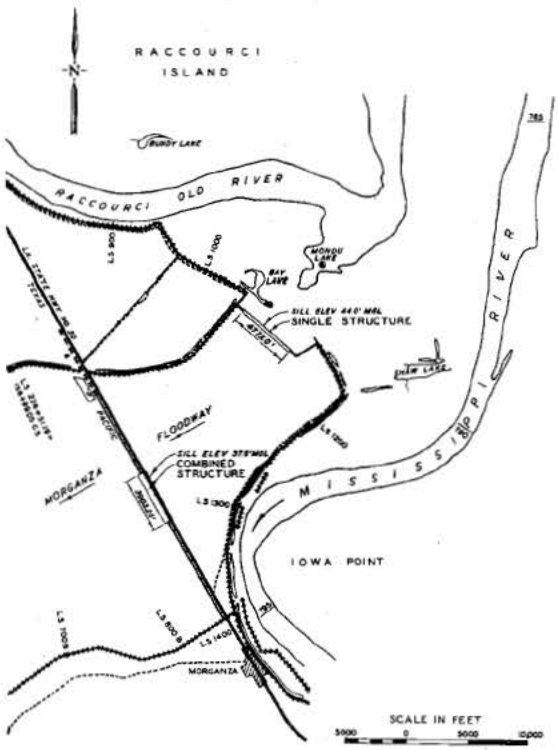

Fig. 2. Location map

3. The second plan studied consisted of a combined railway, highway, and control structure 3,903.25 ft long located about 3 miles down the floodway from the proposed location of the Bonnet Carre type needle structure (fig. 2). The combined structure, which also included needles for regulation of flow, comprised 125 bays, each 28.25 ft wide, separated by piers 3 ft wide. Atop these piers were a narrow-gage railway which carried the equipment required to handle the needles, a single-track line of the Texas and Pacific Railroad, and a state highway. As a result of model tests on the Bonnet Carre type structure, the ogee weir was replaced by a broad-crested weir for the combined structure. The crest of this weir was at elevation 37.5. A horizontal apron on which were located two rows of baffle piers and a

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* All elevations are in feet above mean sea level.

4-ft-high end sill composed the stilling basin (plate 23). The needles have been replaced by gates in the latest plans, and the notch in the weir for seating the needles has been omitted. However, tests were not conducted on a model of the weir with the notch omitted.

Purpose of the Model Studies

4. The general purpose of the model studies was to examine the over-all performance of the proposed control structure with special attention to discharge coefficients, flow conditions at the abutments, and the effectiveness of the stilling basin in dissipating flow under all tailwater conditions.

PART II: THE MODELS

Description

5. Three models were used to accomplish the purpose of the investigation: a 1:16-scale model reproduced the right abutment and adjacent five bays of the Bonnet Carre type needle structure (plate 2 and fig. 3); a 1:30-scale section model reproduced 75 ft of the control weir (two full and two half bays); and a 1:20-scale model reproduced the right abutment and adjacent five bays of the combined railway, highway, and control structure. Originally only the 1:16-scale model was planned; however, as tests progressed, it was found more convenient to conduct tests of various weir shapes on a 1:30-scale section model in an existing flume.

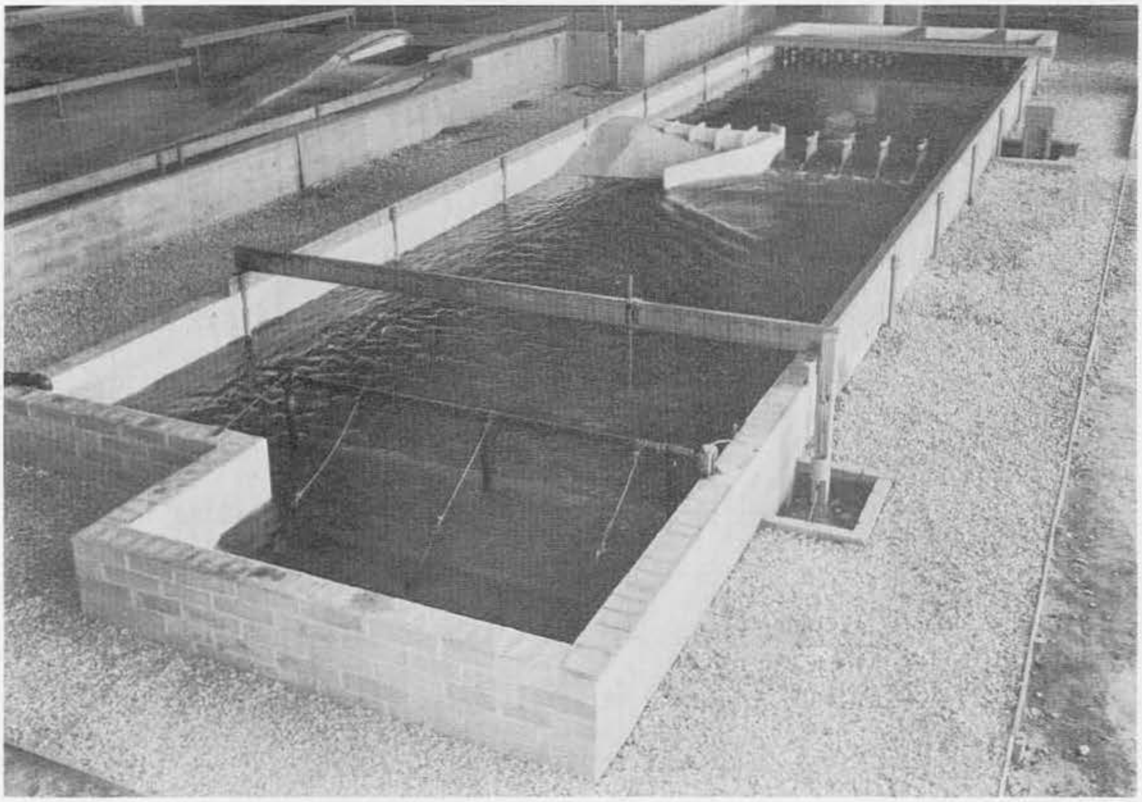


Fig. 3. Model of single control structure with ogee weir installed

The flume used for the 1:16-scale model of the Bonnet Carre type needle structure also was used to contain the model of the combined structure. It was necessary to reduce the model scale to 1:20, however, in order to simulate the larger bays of the combined structure within the limitations of the facilities provided for the original model.

6. The flume used for the two models reproduced approximately 400 ft of approach area, 115 ft of the levee forming the right abutment, five bays of the control structure and the stilling basin downstream therefrom, and 400 ft of exit area. The approach area, levee, and control weir were molded in cement mortar. The crest piers, baffle piers, end sill and stilling-basin floor were modeled in wood. The exit area was either molded in sand or fixed in cement mortar depending upon the nature of the tests being conducted.

7. Water used in the operation of the model was supplied by a circulating system with measurement of discharge being made by venturi meters. Flow from the supply lines spilled into a headbay where it was stilled by baffles prior to its entrance into the model. After passing through the model the water flowed through a return line back to the sump. The tailwater elevation in the downstream end of the model was controlled by an adjustable tailgate. Steel rails, set to grade along both sides of the flume, provided a reference plane for measuring devices. Water-surface elevations were measured both by means of portable point gages (mounted on an aluminum beam supported by the steel rails) and by means of piezometers. Pressures on the weir crest were measured by piezometers. Velocities were measured by means of a pitot tube.

8. The 1:30-scale section model was contained in a glass-sided

flume which was equipped with similar facilities for measuring discharges, water-surface elevations, and velocities.

Scale Ratios

9. The accepted equations of hydraulic similitude, based upon the Froudian relationships, were used to express the mathematical relationships between the dimensions and hydraulic quantities of the model and the full-scale structure. General relationships existing for the three models were as follows:

Ratio		Scale Relationship: Bonnet Carre Type Structure	Combined Structure	Section of Control Weir
Length	L_r	1:16	1:20	1:30
Area	$A_r = L_r^2$	1:256	1:400	1:900
Velocity	$V_r = L_r^{1/2}$	1:4	1:4.472	1:5.477
Discharge	$Q_r = L_r^{5/2}$	1:1024	1:1790	1:4929

10. Measurements in the models of discharges, water-surface elevations, velocities, and pressures (all positive pressures and negative pressures corresponding to pressures above the cavitation range in the prototype) can be transferred quantitatively from model to prototype equivalents by means of the previously mentioned scale relationships. However, judgment must be used in the interpretation of all data, since tests were run under stable conditions which seldom will obtain in the prototype. Evidences of scour are to be considered only qualitatively reliable, since it has not been found possible to reproduce quantitatively in a model the resistance of a prototype bed material. The data on scour tendencies provide a basis for resolving the question as to the

relative effectiveness of types and placement of stilling-basin elements. They also indicate areas most subject to attack. Determination of the actual depth of scour to be expected in the prototype should be predicated upon the magnitude of bottom velocities and characteristics of the prototype bed material.

PART III: TESTS AND RESULTS

Bonnet Carre Type Structure

Weir

11. It is planned that, when the needles used to close the spillway bays are first withdrawn, flow will pass over the weir into an empty stilling basin, thus meeting no resistance from tailwater. However, as the floodway fills, the effect of tailwater on discharge will be felt. The depth of tailwater will increase until only about 1-ft head differential obtains between the headwater and tailwater. Therefore, it was desirable to calibrate the model weir under a complete range of headwater-tailwater relationships. This was accomplished in the model by setting several constant discharges and varying the tailwater, for each discharge, from the minimum possible tailwater to one which caused the gross head to rise above elevation 57.8, the anticipated maximum stage of the Mississippi River. The family of curves obtained is shown on plate 3. From these curves a discharge coefficient, C, for free flow (no tailwater effect) was computed; then a curve showing the effect of various tailwater depths on the discharge coefficient was developed. These latter curves are plotted on plate 4. It was possible to determine by trial and error a head-discharge curve for the structure, shown on plate 5, based on the data contained on plate 4 and on the computed tailwater curve also shown on plate 5. The structure was found capable of discharging about 530,000 cfs at the design head of 13.8 ft. This discharge was in excess of the 490,000 cfs expected at the design head. Therefore a discharge of 490,000 cfs was used and the head permitted to drop to elevation 56.9

in succeeding tests of the type 1 spillway.

12. Piezometers were installed in the weir of original design to determine pressure conditions thereon. All pressures were positive for conditions of controlled tailwater (pool elevation 56.9, tailwater elevation 55.7). Controlled tailwater is defined as that tailwater at which the gross head-tailwater-discharge relationships shown on plate 5 obtained. However, the notch which provides a seat for the needles caused local flow disturbance and produced pressures on the weir as low as -1.8 ft with the pool at elevation 53.6, a discharge of 490,000 cfs, and no tailwater effect, conditions that will obtain when the first needles are withdrawn. Negative pressures of this magnitude are felt to be of no consequence. Plates 6 and 7 and table 1 contain pressure data.

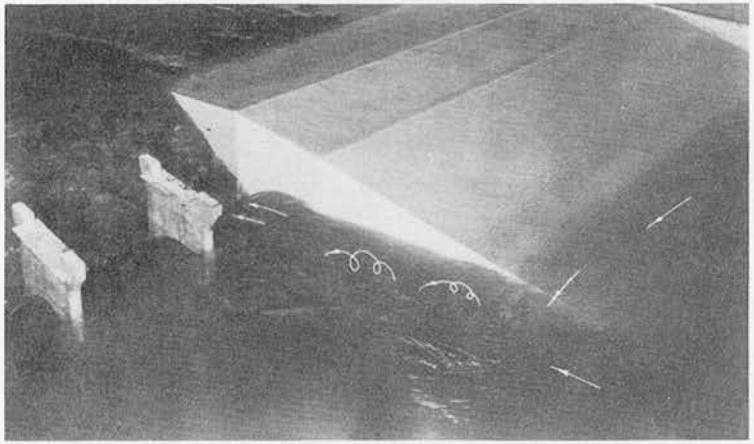
13. Tests were conducted on the 1:30-scale section model described in paragraph 5 to determine the effect of weir shape on discharge coefficients, with particular attention to submerged flows. The weir of original design and three modifications thereof were tested. These modifications consisted of addition of 5-, 10-, and 15-ft horizontal sections at the crest (plate 8). The procedure described in paragraph 11 was followed in calibrating these weirs. Relationships between gross head and tailwater for various discharges are shown on plates 9-12. The nature of the Morganza Floodway operations will be such that maximum efficiency of the control structure will be desirable at the maximum head. Efficiency at lesser heads or prior to the tailwater build-up will not be as critical. Thus discharge over the four types of weirs tested was compared for the maximum head of 13.8 ft. The relationships of discharge and tailwater for a gross head of 13.8 ft on the weirs are

plotted on plate 13. It is to be noted that for tailwater conditions expected at the control structure the type 2 weir discharged about 3.4 per cent more water than did the type 1 weir while the types 3 and 4 weirs discharged about 4.0 and 4.5 per cent more, respectively. In a conference with representatives of the Mississippi River Commission it was agreed that the discharge capacity to be gained by a weir having a crest wider than 5 ft (type 2) was not sufficient to warrant the extra concrete required for construction. Thus it was agreed tentatively that the weir of final design would have a 5-ft-wide crest.

Abutment walls

14. The abutment walls of original design, type A, were shaped to the cross section of the levee and in plan were flared 1 on 4 in upstream and downstream directions (plate 14). The levee extended to the abutment wall. Tests revealed considerable turbulence at the junction of the flow along the levee and the high-velocity flow approaching the weir (figs. 4 and 5). Also the velocities along the levee itself were such that protection would be necessary. Flow in the exit surged over the wall and onto the downstream toe of the levee (fig. 6).

15. Consideration was given to improving flow conditions at the abutment by joining the weir abutment to the levee by a nonoverflow concrete section and increasing the height of the abutment walls to the maximum water-surface elevation. The type B abutment wall (plate 14) was tested in order to ascertain whether conditions in the approach would be appreciably improved by use of a wall extending above the maximum water surface. Flow along the type B abutment wall was less turbulent than that along type A (compare figs. 4 and 7). Surge conditions over



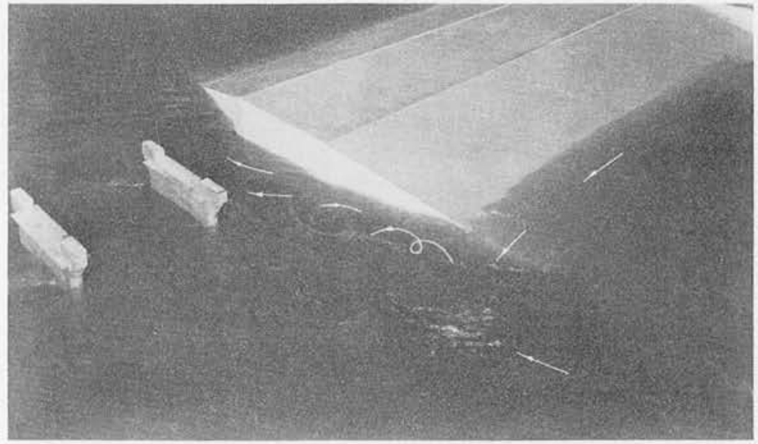


Fig. 4. Pool elev 53.6; minimum tailwater
Discharge 490,000 cfs

Fig. 5. Pool elev 56.9; tailwater elev 55.7
Discharge 490,000 cfs

Note turbulence at junction of flow along levee and flow approaching type 1 weir with type A abutment wall

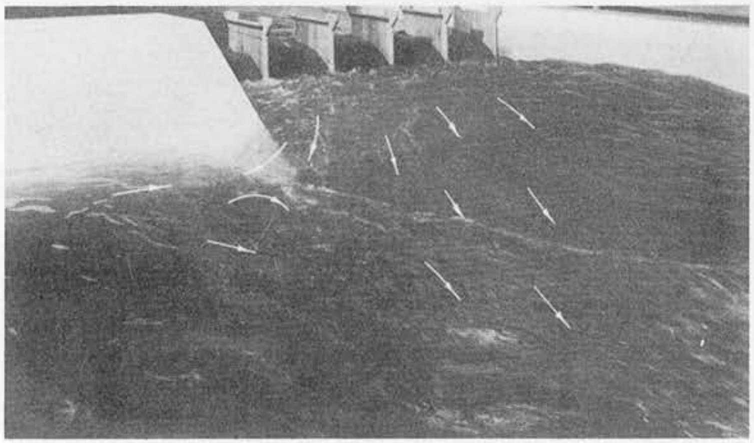


Fig. 6. Free flow over type 1 weir with type A abutment wall, no baffle piers, 490,000 cfs. Flow surges over downstream wall onto levee toe

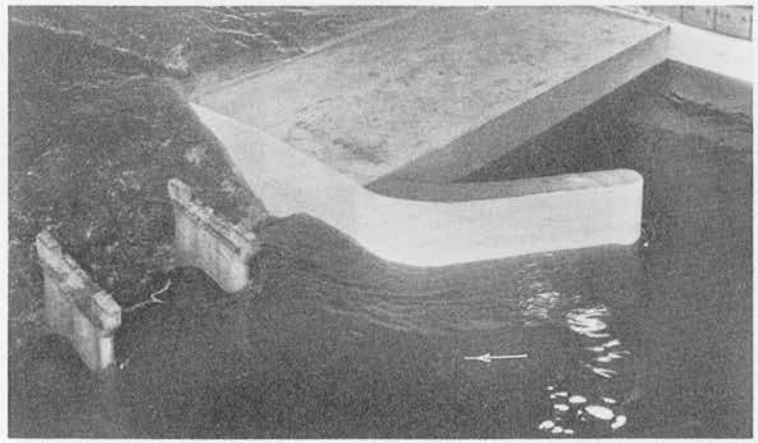
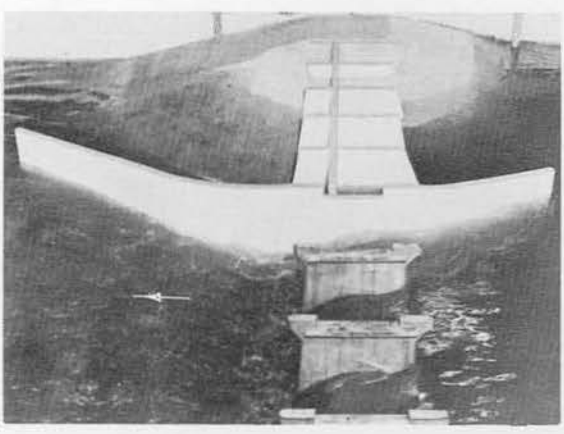


Fig. 7. Free flow over type 1 weir with type B abutment wall, discharge 490,000 cfs. Flow is less turbulent than along type A wall

the downstream toe of the levee were still present.

16. Tests were then made with movable, sheet-metal walls to determine the optimum flare for the approach and exit portions of the wall. The flare for the type C wall, plate 15, was developed by this method. Any greater flare produced more turbulent conditions in the approach and an eddy against the wall in the exit. Flow conditions along the type C wall, figures 8 and 9, were better than those along any other wall tested, although there was still turbulence in the approach. Velocities along the toe of the levee were so low as to be of no concern. The proposed concrete nonoverflow section joining the levee and the abutment wall was installed during these tests.

17. Types C-1, C-2, and C-3 walls (plate 15) were tested in an effort to decrease the length of the approach walls. Flow conditions produced by these walls were not as satisfactory as those produced by the type C wall (figs. 10-12). Velocities along the upstream toe of the levee were of sufficient magnitude to require protection against scour for each of these walls.



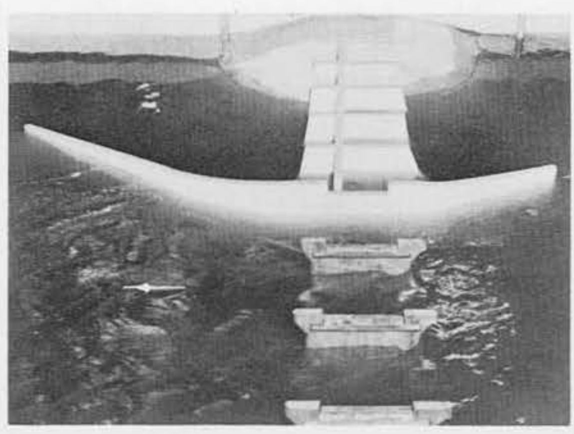


Fig. 8. Free flow　　　Fig. 9. Tailwater elev 55.7
Type 1 weir, type C abutment wall, discharge 490,000 cfs
Note improved flow along wall; flow in approach is still turbulent

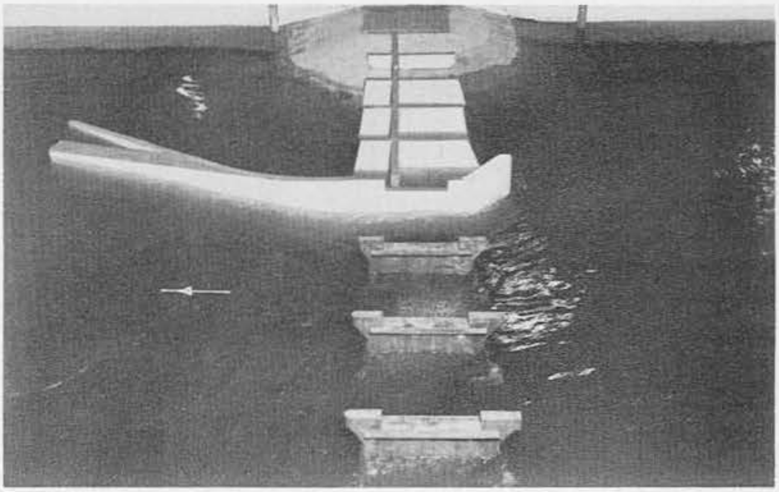


Fig. 10

Type C-1 abutment wall
discharge 490,000 cfs
pool elev 56.9
tailwater elev 55.7

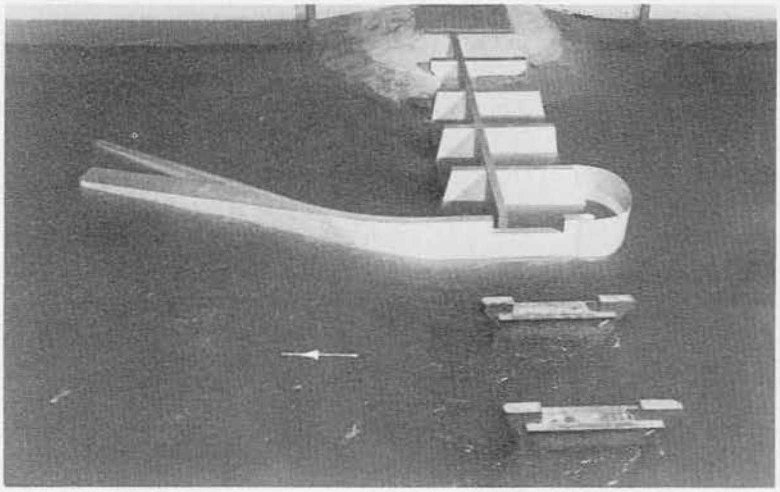


Fig. 11

Type C-2 abutment wall
discharge 490,000 cfs
pool elev 56.9
tailwater elev 55.7

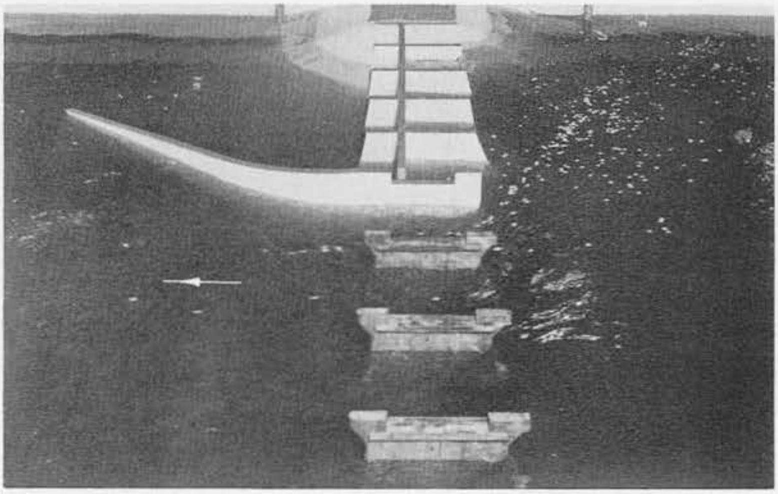


Fig. 12

Type C-3 abutment wall
discharge 490,000 cfs
pool elev 56.9
tailwater elev 55.7

Flow over type 1 weir with the types C-1, C-2, or C-3 abutment walls installed was not as satisfactory as flow with the type C abutment wall

Stilling basin

18. A flow of 490,000 cfs produced maximum velocities of 18.4 ft per sec on the bed of the exit channel (plate 16) with the tailwater in the exit channel set as low as possible and with the bed molded flat at elevation 40. These same conditions were used in a scour test (exit area molded in sand) of one-hour duration and eroded a hole 10 ft deep in the channel bed (plate 17). The same discharge with controlled tailwater produced maximum bottom velocities of only 6.4 ft per sec (plate 18) and the resulting scour hole was only 3 ft deep (plate 19).

19. The baffle blocks were removed from the apron and with free flow conditions it was found that velocities over the end sill were approximately 4 ft per sec greater than those which obtained with the baffles on the apron (compare plates 16 and 20). Also the maximum scour hole was only 2 ft deeper without baffles (compare plates 17 and 21). However, these tests were made for constant flow conditions and do not reveal the value of the baffle piers in dispersing the jets when the bays were first opened and no tailwater depth existed. No tests were conducted with single gate operation since it was believed that flow would be distributed sufficiently by the baffle piers and end sill to prevent excessive erosion.

20. A study of the effect of stilling basin length on energy dissipation was made by obtaining velocity measurements along the center line of the test section for various apron lengths and free-flow conditions. It was realized that velocities in the model with free-flow conditions would not accurately reproduce those in the prototype, but the test results are considered to provide comparative data on which to base

stilling-basin length. The baffle piers were removed from the apron for these tests. It may be noted from data presented on plate 22 that velocities in the exit channel were about 17.5 ft per sec, regardless of the apron length used. The 60-ft-long apron (type 2) was the shortest tested wherein impact of flow on the end sill did not appear excessive and velocities immediately over the end sill did not exceed the velocities observed further down the exit channel. Therefore the 60-ft-long apron appears to be about the minimum length possible. Flow conditions in the stilling basin with a 60-ft apron and no baffle piers are shown by figure 13.

Fig. 13. Flow of 200,000 cfs into stilling basin having a 60-ft apron, end sill, and no baffle piers; minimum tailwater

21. Attention is invited to the fact that reproduction of only five bays in the model produced an unnatural confining of flow over the end sill in the model for minimum tailwater conditions in the exit channel. Prototype flow under the same headwater elevation and with only five bays open would not be confined over the end sill as it was in the model. The minimum tailwater, on the other hand, would be higher in the prototype than that which existed in the model when the structure is discharging

490,000 cfs. If prototype performance indicates that 490,000 cfs cannot be passed at the desired headwater elevation the tailwater below the structure will have to be lowered by cleaning the floodway or by other means so that the design flow can be obtained. Therefore, in view of the possibility of lower tailwater elevations than those used in the model and the various conditions under which the bays will be opened, it was decided by the Mississippi River Commission to maintain the length of the stilling basin as originally designed.

Combined Structure

22. Details of the revised plans combining the control structure with a highway and railway bridge are shown on plate 23. As stated previously, the combined structure was investigated on a 1:20-scale model reproducing the right abutment and five adjacent gate bays (fig. 14). The changes in the over-all plan provided for passage of about 600,000 cfs through the floodway.

Weir

23. The weir (type 5) for the combined structure (plate 23)

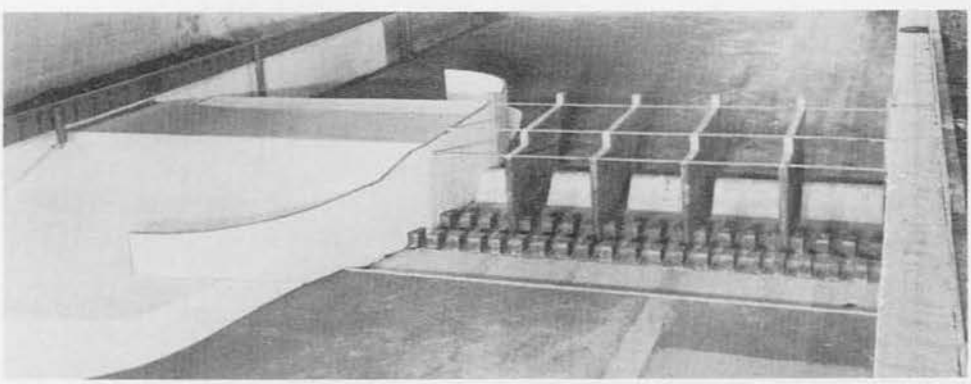


Fig. 14. 1:20-scale model of combined structure

consisted of a simplified version of the type 2 weir previously tested. It embodied a notch for support of the needles and a horizontal crest at elevation 37.5 connected to the apron by a 1-on-1 slope. Calibration was made by the method described in paragraph 11. Submergence curves, discharge coefficients, and rating curves are shown on plates 24-26. The fact that there is less spread between the headwater and tailwater curves on plate 26 than there is on plate 5 demonstrates that the type 5 weir is more efficient for conditions expected than is the type 1 weir.

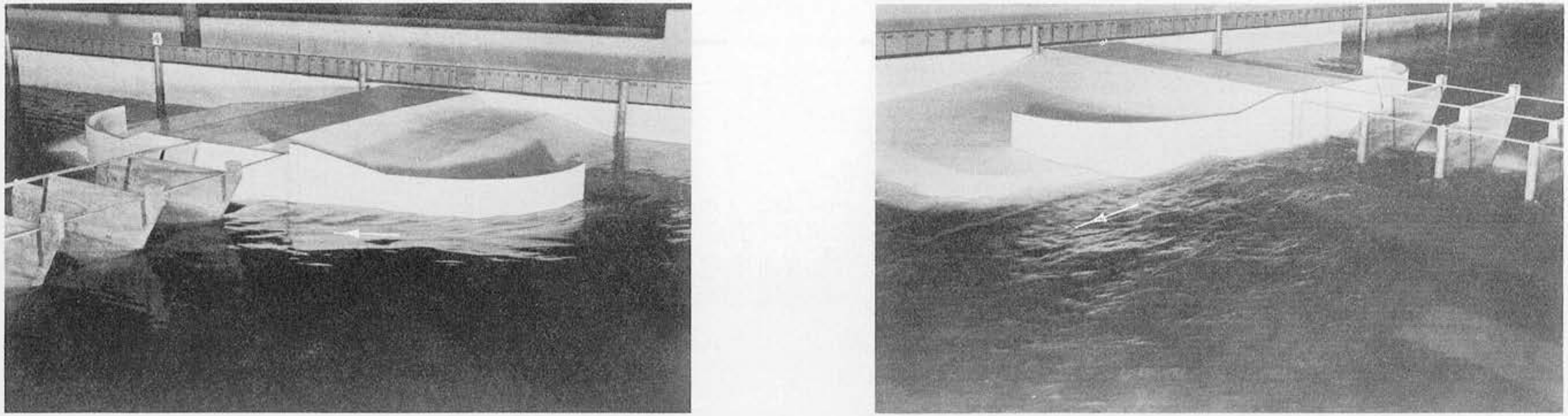
24. Pressures as low as -4.5 ft were measured on the downstream face of the weir for free flow conditions (plate 27 and table 2). However, it is felt that negative pressures of this magnitude are of no concern, since the depth of tailwater at the prototype site will increase rapidly. Pressures are positive with high tailwater (plate 28).

Abutment walls

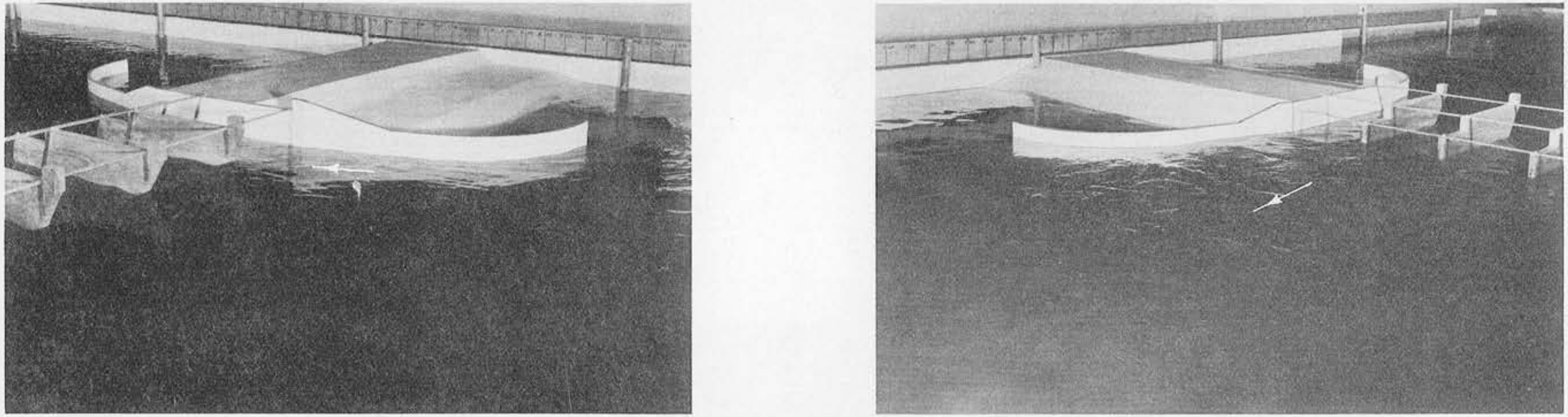
25. The abutment walls for the combined structure, proposed by Mississippi River Commission engineers and designated type D herein, were curved and extended above the maximum expected water surface and the levee was extended to the abutment wall (fig. 14). Flow conditions around the type D abutment walls (fig. 15) were generally satisfactory. Turbulence along the wall was about equal in intensity to that along the type C wall described in paragraph 16.

Stilling basin

26. The stilling basin proposed by the Mississippi River Commission for the combined structure consisted of a horizontal apron 86.9 ft long, two rows of baffle piers, and a 4-ft-high end sill. This stilling basin



Pool elev 47.2; minimum tailwater



Pool elev 51.4; tailwater elev 50.6

Fig. 15. Flow conditions with type D abutment walls and discharge of 400,000 cfs

satisfactorily dissipated all flows. Baffle piers were required to disperse the jet immediately after the gates were opened prior to any tailwater build-up. Velocities measured around the abutment walls and in the exit area are presented on plates 29-32.

PART IV: CONCLUSIONS AND RECOMMENDATIONS

27. The model study of the control structure for the Morganza Floodway demonstrated that for the submerged conditions expected at the control structure a 5-ft-wide broad-crested weir will discharge about 3.4 per cent more water than will an ogee weir. This increase resulted from the more nearly horizontal flow paths over the broad-crested weir which lessened interference by tailwater.

28. The abutment walls should extend above the maximum expected water surface. The wall in the approach should be carried at least 55 ft upstream from the weir crest. The amount of flare in the approach did not appear to be critical but should not exceed 1 on 2 nor be less than 1 on 4. The wall in the exit should be carried to the end sill and should be flared at the rate of not more than 1 on 3.

29. Uncertainties regarding tailwater elevation and method of operation led to a decision by personnel of the Mississippi River Commission to maintain the original design basin length, although tests indicated that the length of the basin might be reduced to about 60 ft. Baffle piers are needed on the apron to disperse the jet entering the stilling basin as soon as the needles are withdrawn and prior to build-up of the tailwater. A 4-ft-high sloping end sill satisfactorily deflected the flow from the apron into the exit area. Tests were not conducted with the elevation of the apron varied, because the elevation of original design was satisfactory from a hydraulic standpoint and was optimum from a foundation standpoint.

30. The stilling basin was found necessary to dissipate flow only

until such time as the tailwater had risen sufficiently to cause 0.8 submergence. Consideration should be given, therefore, to construction of a stilling basin downstream from only the minimum number of gate bays which will allow the tailwater to build up to about 0.8 submergence. Flow over the weir swept along the surface of the tailwater at submergences of 0.8 and greater, and a stilling basin was not required. The possibility that the tailwater may be lowered in the future, however, would require that the basin be constructed below a sufficient number of bays to pass the flow necessary to secure 0.8 submergence.

TABLES

Table 1

PRESSURES ON TYPE 1 WEIR

Discharge	Tailwater	Piezometer Number 1	2	3	4	5	6	7	8	9	10
200,000	Minimum	5.9	4.4	4.7	1.0	2.5	2.7	1.8	1.8	4.2	8.4
	Controlled	6.1	4.8	5.0	1.9	3.1	3.4	3.5	5.8	8.6	11.4
300,000	Minimum	6.6	5.0	5.3	0.5	2.5	2.9	2.1	2.3	5.2	10.1
	Controlled	8.9	7.5	7.8	5.2	6.3	6.7	7.8	9.7	11.9	14.4
400,000	Minimum	6.7	4.8	5.9	-0.7	2.3	2.8	2.2	2.9	6.8	11.2
	Controlled	10.7	9.6	9.7	7.5	8.5	8.9	9.9	11.8	14.0	16.5
490,000	Minimum	6.9	4.8	6.2	-1.8	1.7	2.6	2.2	3.5	7.9	11.9
	Controlled	12.5	11.4	11.6	9.5	10.4	10.7	11.9	13.8	16.0	18.5

Note: Piezometer locations shown on plate 6.
Pressures recorded in prototype feet of water.

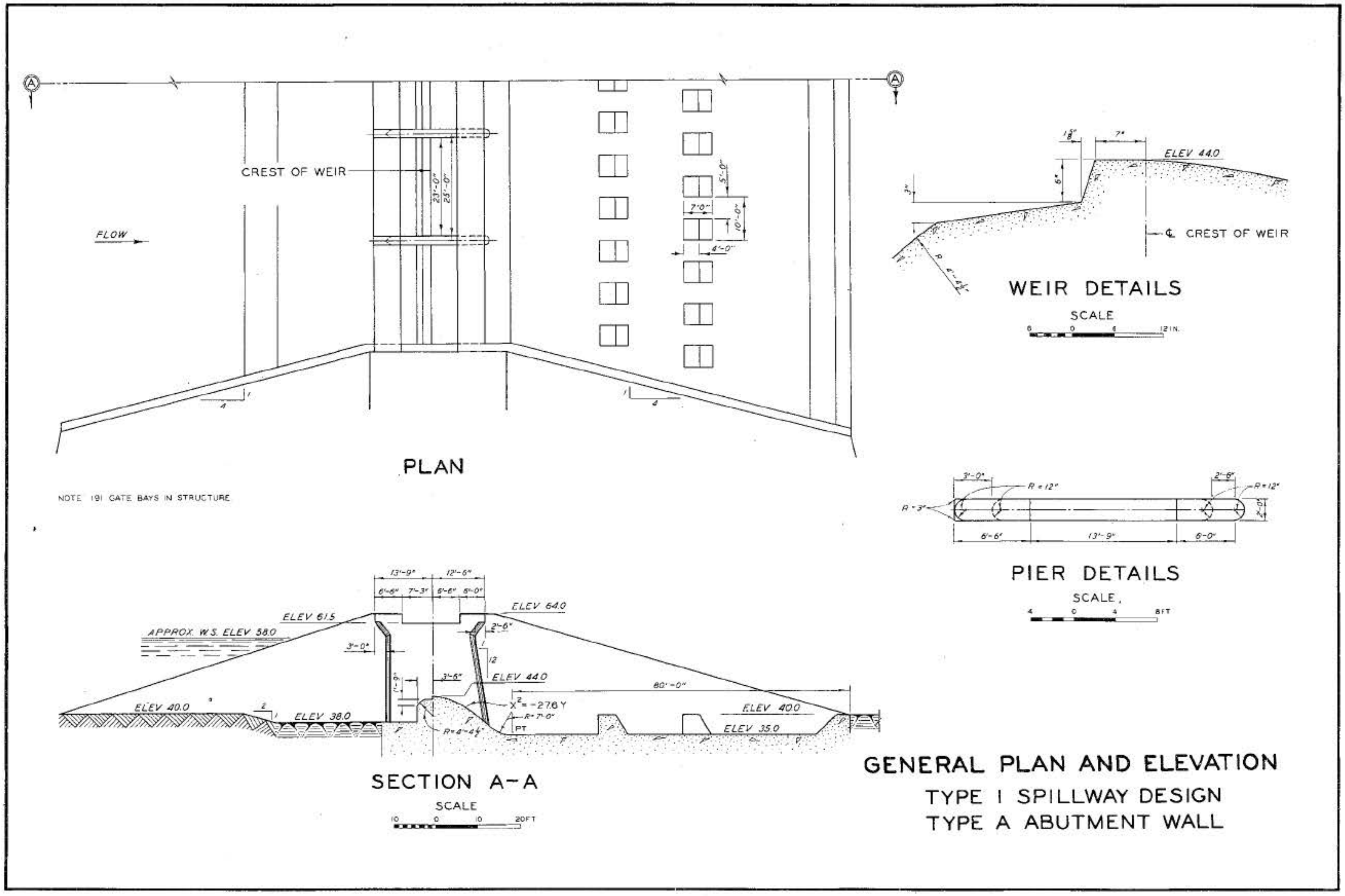
Table 2

PRESSURES ON TYPE 5 WEIR

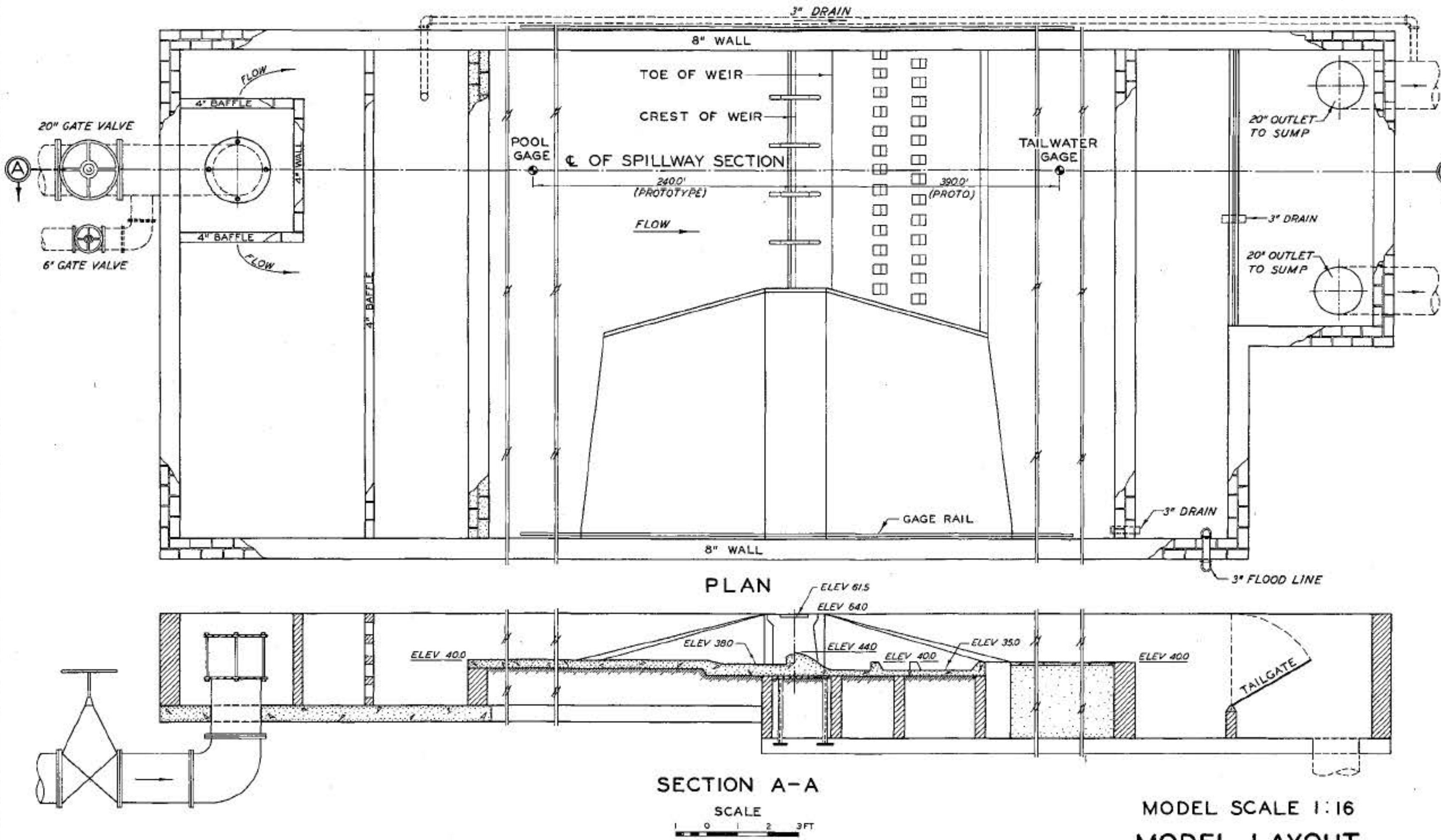
Discharge	Tailwater	Piezometer Number 1	2	3	4	5	6	7	8	9	10
161,095	Minimum	8.2	4.8	5.1	1.3	1.0	-1.9	-3.1	0.1	2.1	5.5
	Controlled	9.4	6.8	7.0	5.5	6.1	6.3	7.1	8.0	9.5	12.4
207,461	Minimum	8.4	4.9	5.8	1.8	1.5	-1.5	-2.2	0.9	3.1	7.8
	Controlled	10.9	8.3	8.5	6.7	6.7	6.8	7.4	8.3	9.8	12.7
304,800	Minimum	9.9	5.7	6.8	1.5	1.1	-3.0	-3.8	0.3	3.4	8.3
	Controlled	13.5	10.9	11.2	9.9	10.5	10.6	11.2	12.1	13.6	16.5
383,900	Minimum	10.6	5.6	7.5	0.8	0.8	-3.9	-4.5	0.5	4.1	9.5
	Controlled	15.6	12.9	13.0	11.8	12.4	12.6	13.5	14.4	15.8	18.7
464,500	Minimum	11.3	5.6	7.9	0.0	0.5	-4.3	-5.0	1.1	5.7	11.1
	Controlled	17.3	14.5	14.7	13.4	13.9	14.1	15.1	16.0	17.5	20.4
600,300	Minimum	12.7	5.8	9.1	0.0	1.7	-4.5	-3.9	2.9	7.6	11.5
	Controlled	20.2	17.3	17.6	16.2	16.8	17.2	18.1	19.0	20.5	23.4

Note: Piezometer locations shown on plate 27.
Pressures recorded in prototype feet of water.

PLATES



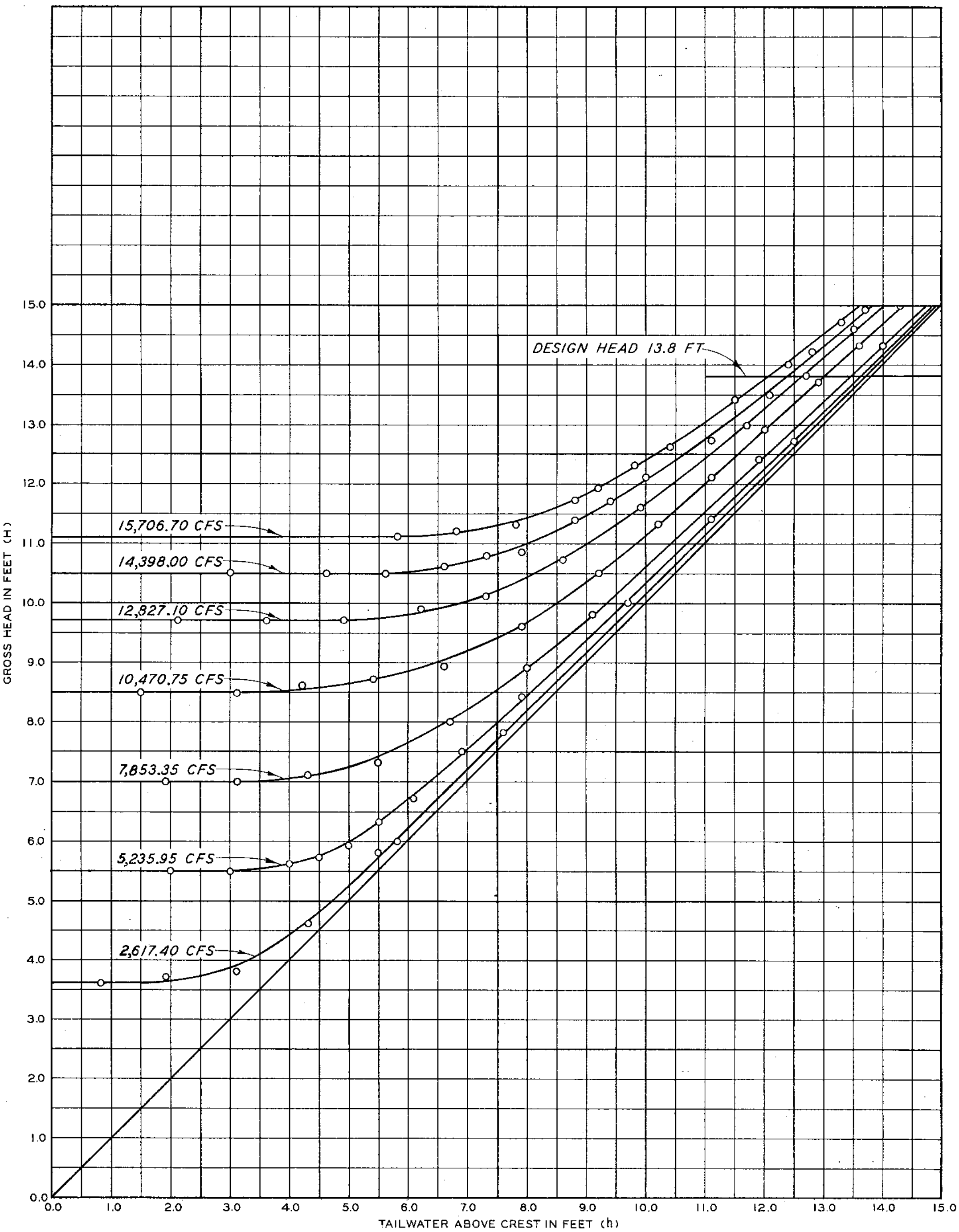
GENERAL PLAN AND ELEVATION
TYPE 1 SPILLWAY DESIGN
TYPE A ABUTMENT WALL



MODEL SCALE 1:16

MODEL LAYOUT

TYPE 1 SPILLWAY DESIGN
TYPE A ABUTMENT WALL

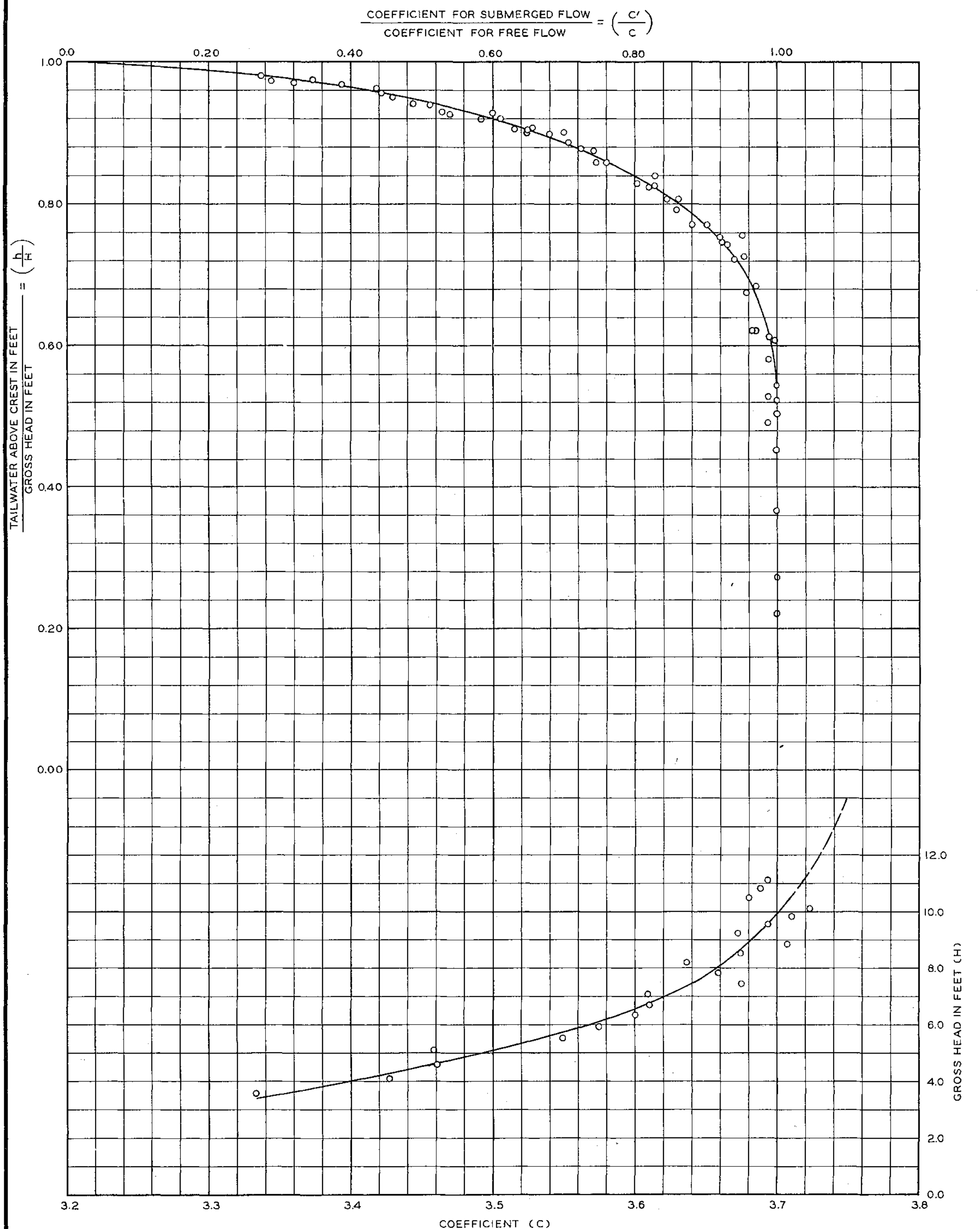


MODEL SCALE 1:16

SUBMERGENCE CURVES

TYPE I SPILLWAY DESIGN
TYPE A ABUTMENT WALL

NOTE: DISCHARGE FOR 5 BAYS.



COEFFICIENT $C' = \frac{Q}{LH^{\frac{3}{2}}}$

NOTE: PIER CONTRACTION EFFECTS INCLUDED IN COEFFICIENTS C AND C′.

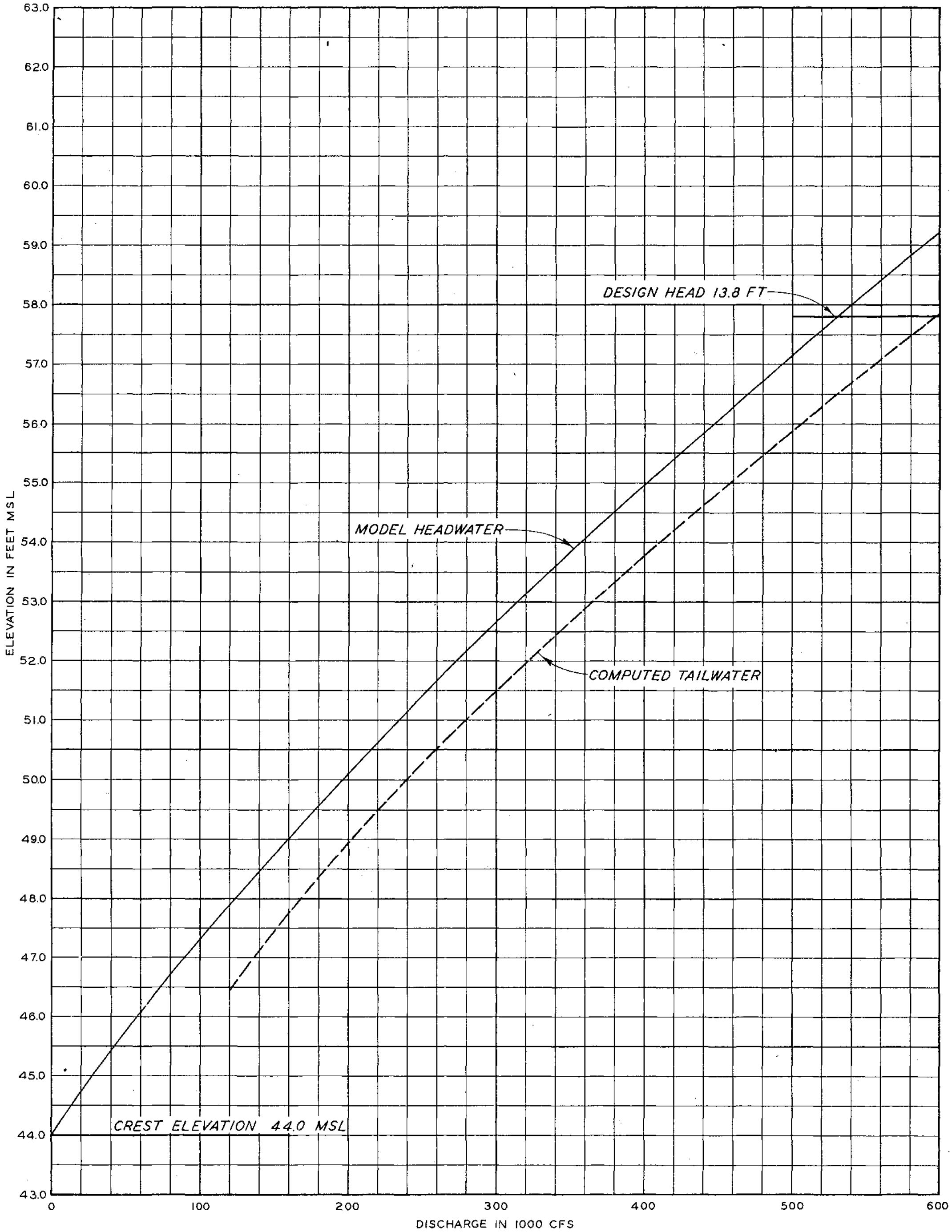
MODEL SCALE 1:16

DISCHARGE COEFFICIENTS

TYPE I SPILLWAY DESIGN

TYPE A ABUTMENT WALL

PLATE 4

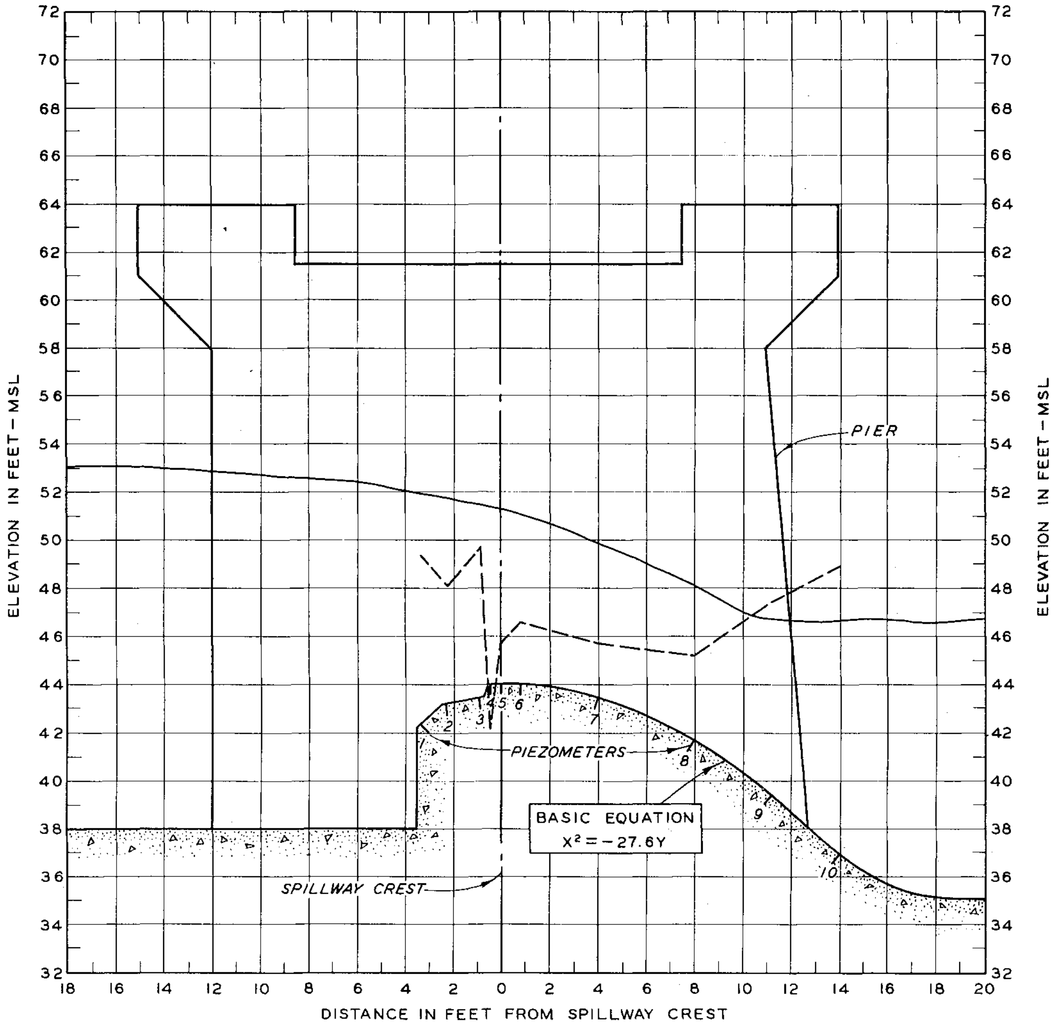


MODEL SCALE 1:16

HEADWATER - TAILWATER CURVES

TYPE I SPILLWAY DESIGN

TYPE A ABUTMENT WALL



LEGEND

—— WATER-SURFACE PROFILE

– – – PRESSURE PROFILE

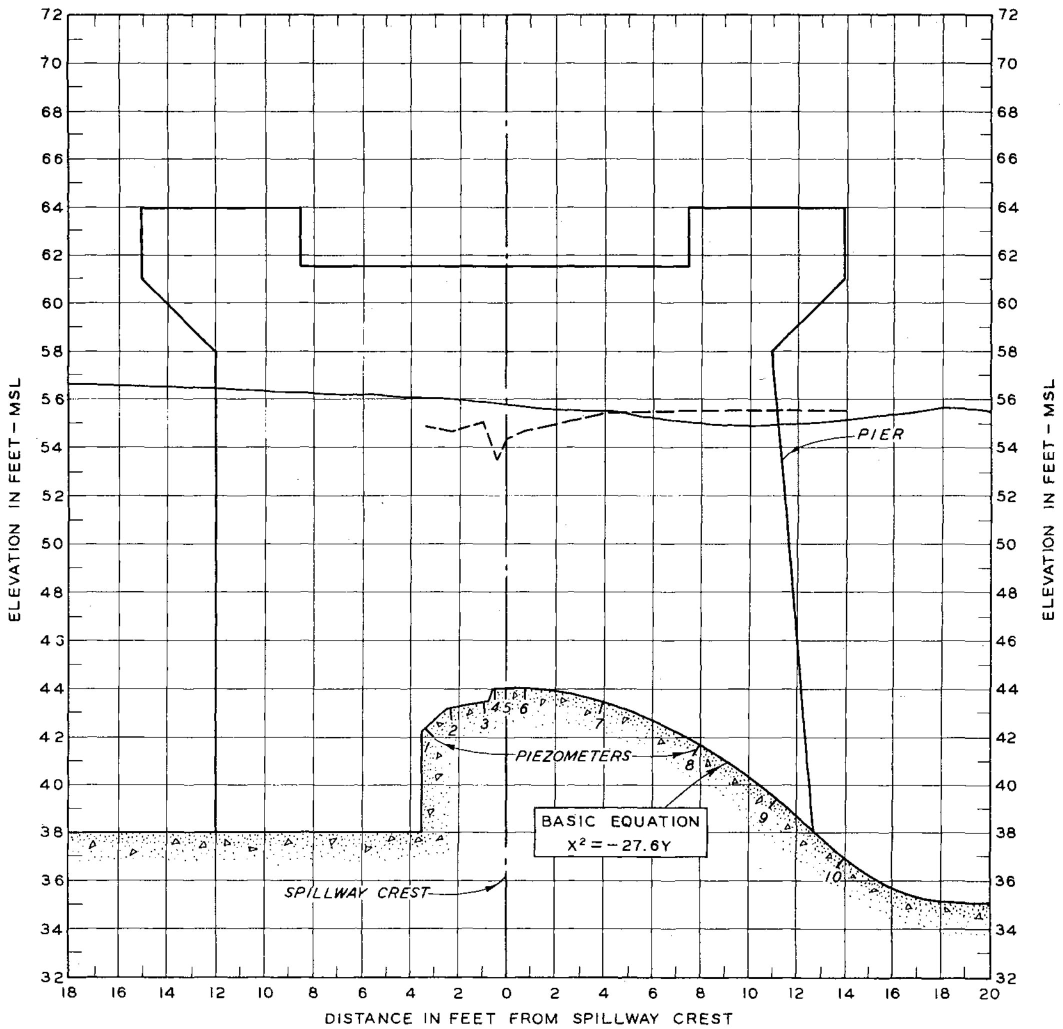
PIEZ NUMBER	PIEZ ZERO	PIEZ READING	PRESSURE
1	42.4	49.3	6.9
2	43.3	48.1	4.8
3	43.5	49.7	6.2
4	44.0	42.2	-1.8
5	44.0	45.7	1.7
6	44.0	46.6	2.6
7	43.5	45.7	2.2
8	41.7	45.2	3.5
9	39.5	47.4	7.9
10	37.0	48.9	11.9

MODEL SCALE 1:16

WATER SURFACE AND PRESSURE PROFILES

TYPE I SPILLWAY DESIGN
TYPE A ABUTMENT WALL

DISCHARGE 490,000 CFS
POOL ELEV 53.6
TAILWATER ELEV MINIMUM



LEGEND

——— WATER-SURFACE PROFILE
– – – – PRESSURE PROFILE

PIEZ NUMBER	PIEZ ZERO	PIEZ READING	PRESSURE
1	42.4	54.9	12.5
2	43.3	54.7	11.4
3	43.5	55.1	11.6
4	44.0	53.5	9.5
5	44.0	54.4	10.4
6	44.0	54.7	10.7
7	43.5	55.4	11.9
8	41.7	55.5	13.8
9	39.5	55.5	16.0
10	37.0	55.5	18.5

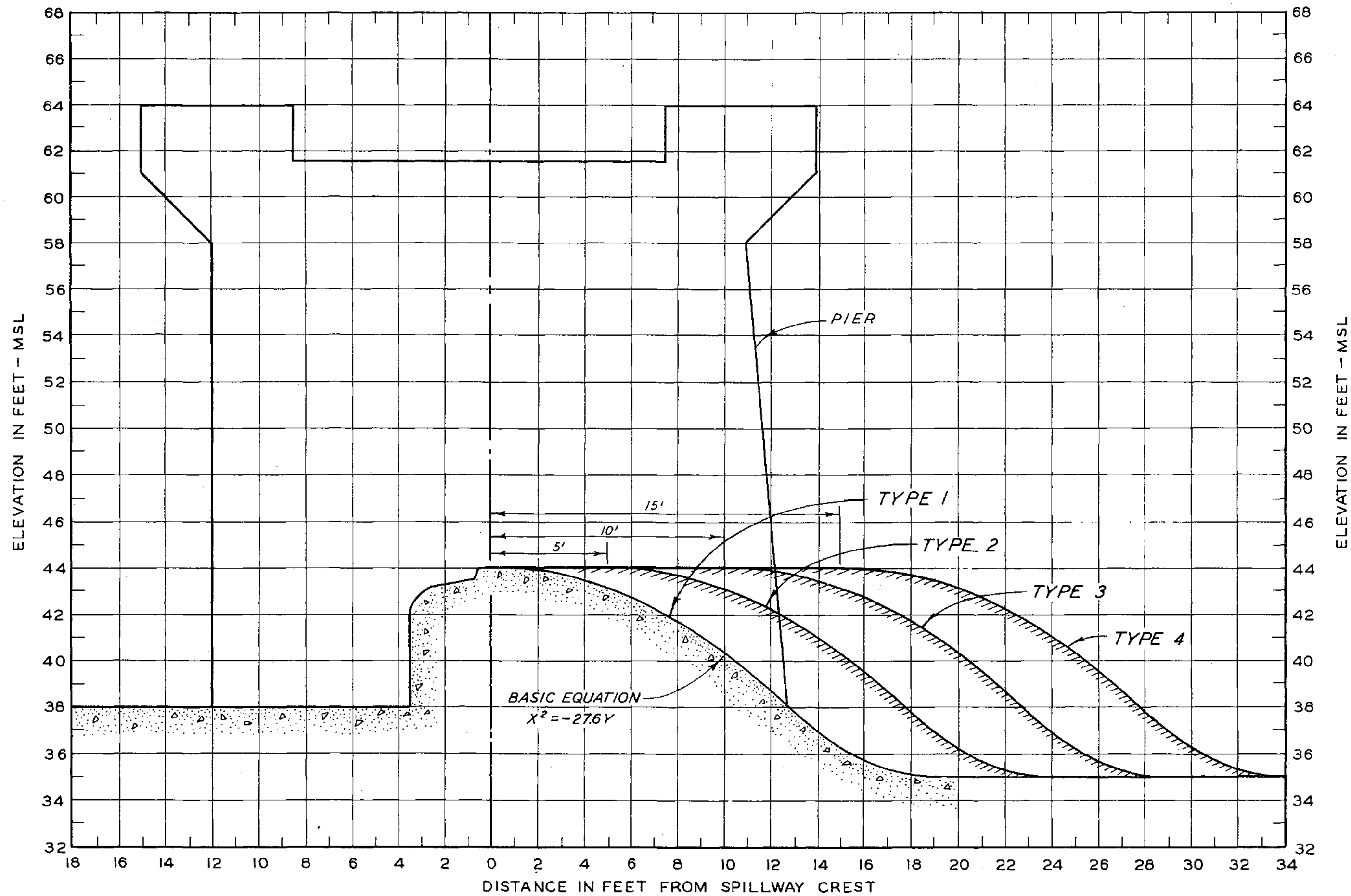
MODEL SCALE 1:16

WATER SURFACE AND PRESSURE PROFILES

TYPE I SPILLWAY DESIGN
TYPE A ABUTMENT WALL

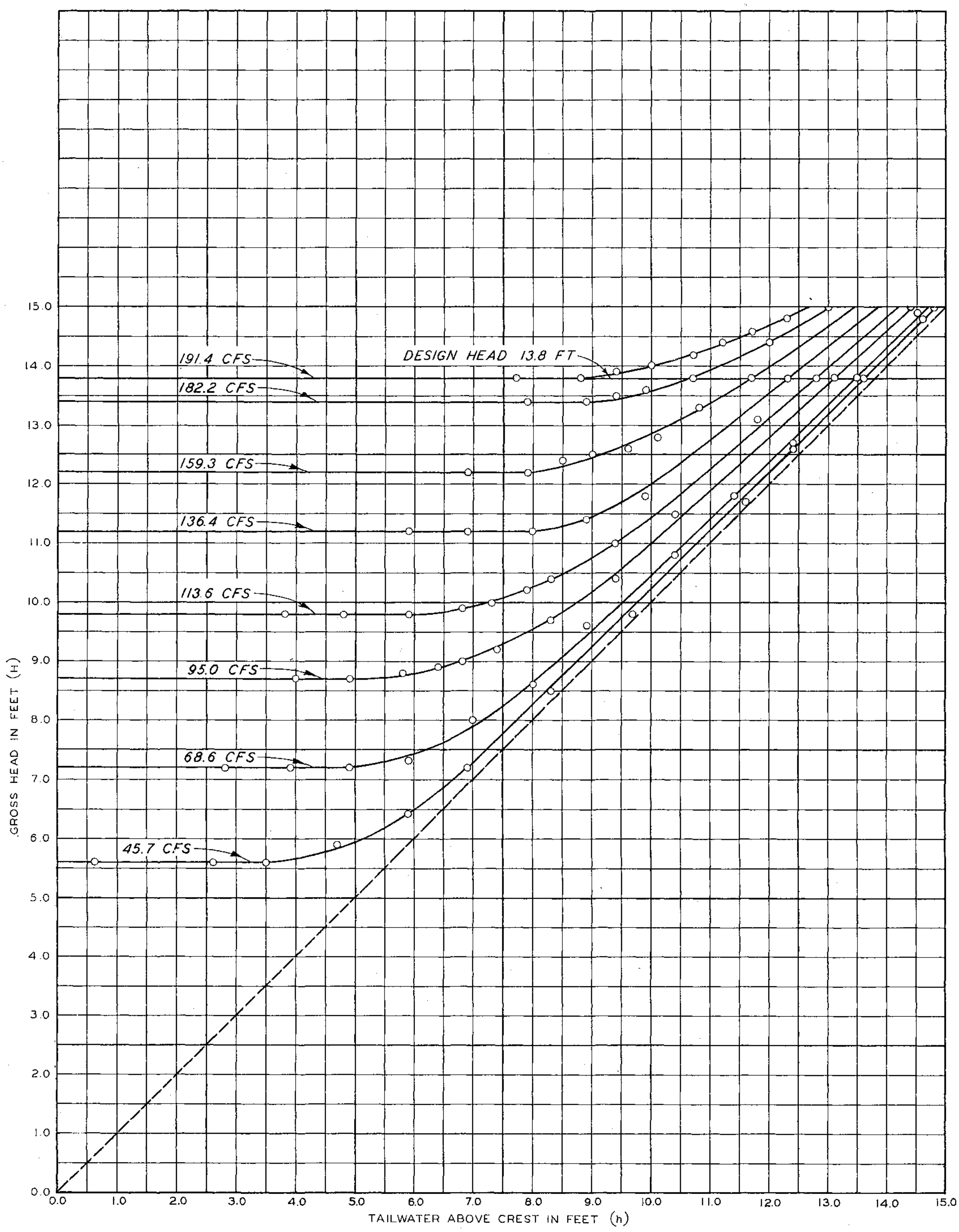
DISCHARGE 490,000 CFS
POOL ELEV 56.9
TAILWATER ELEV 55.7

PLATE 8



MODEL SCALE 1:30

TYPES 1-4 WEIRS

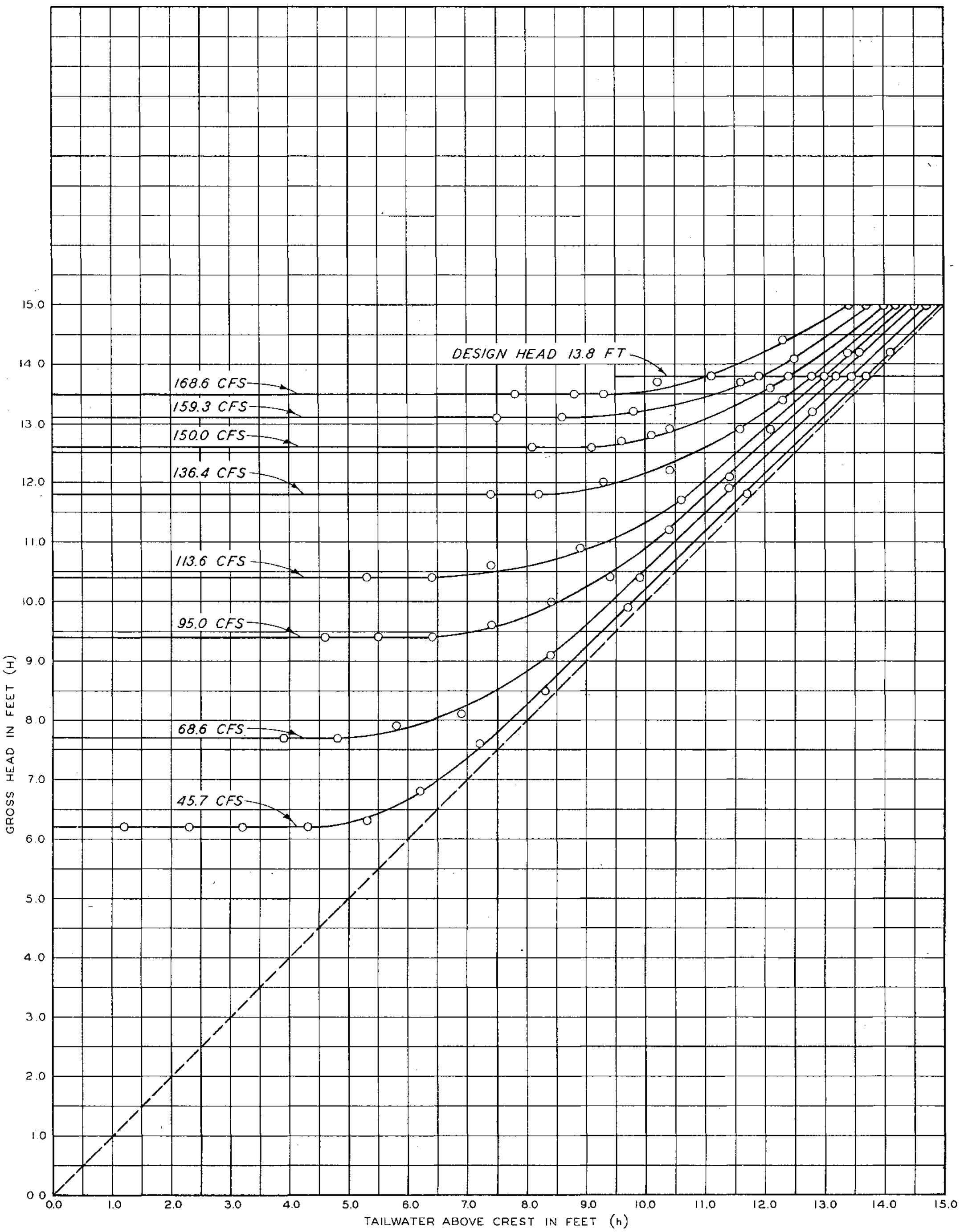


NOTE: DISCHARGE IN CFS PER FOOT OF WEIR

MODEL SCALE 1:30

SUBMERGENCE CURVES

TYPE I WEIR

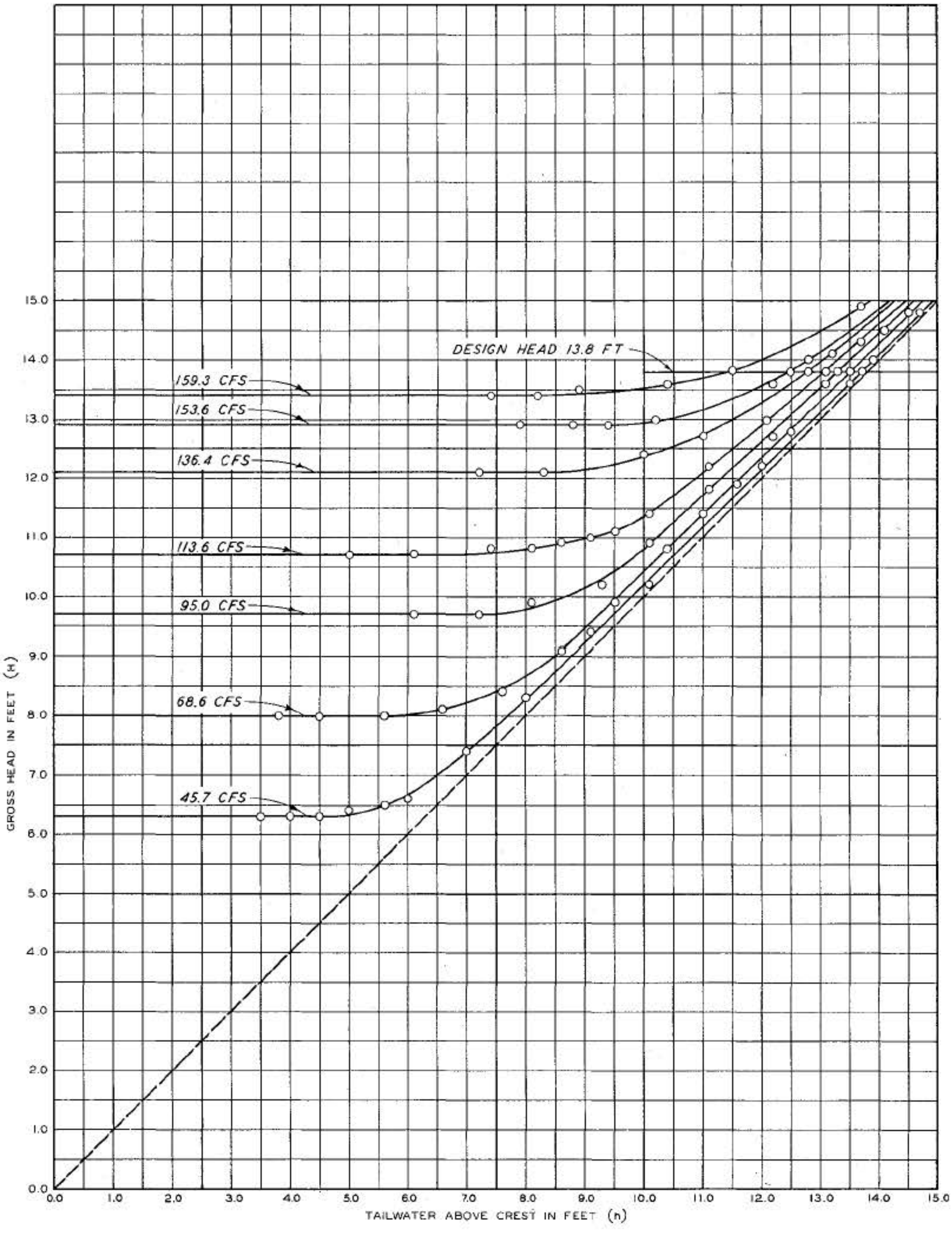


NOTE: DISCHARGE IN CFS PER FOOT OF WEIR

MODEL SCALE 1:30

SUBMERGENCE CURVES

TYPE 2 WEIR

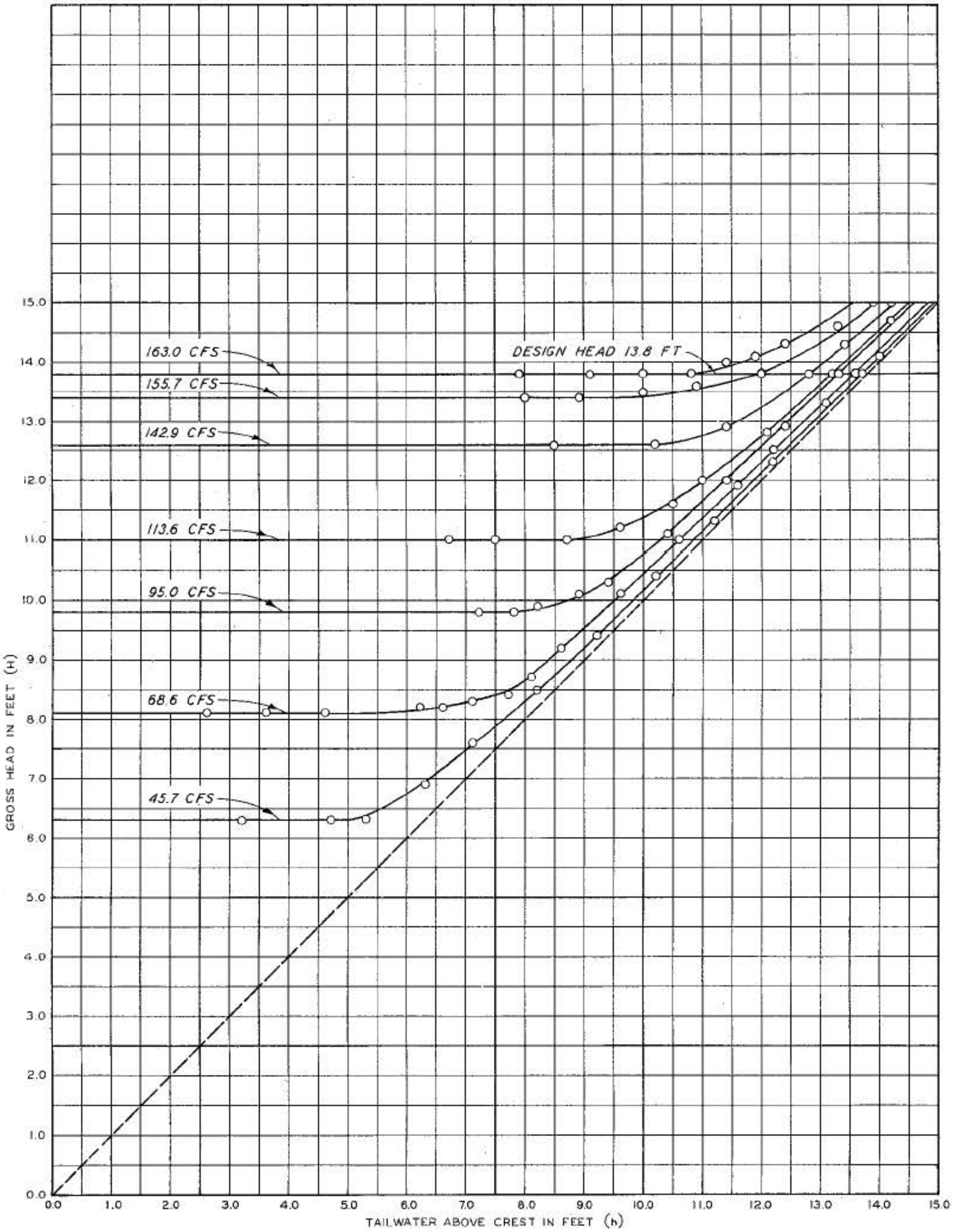


MODEL SCALE 1:30

NOTE: DISCHARGE IN CFS PER FOOT OF WEIR

SUBMERGENCE CURVES

TYPE 3 WEIR

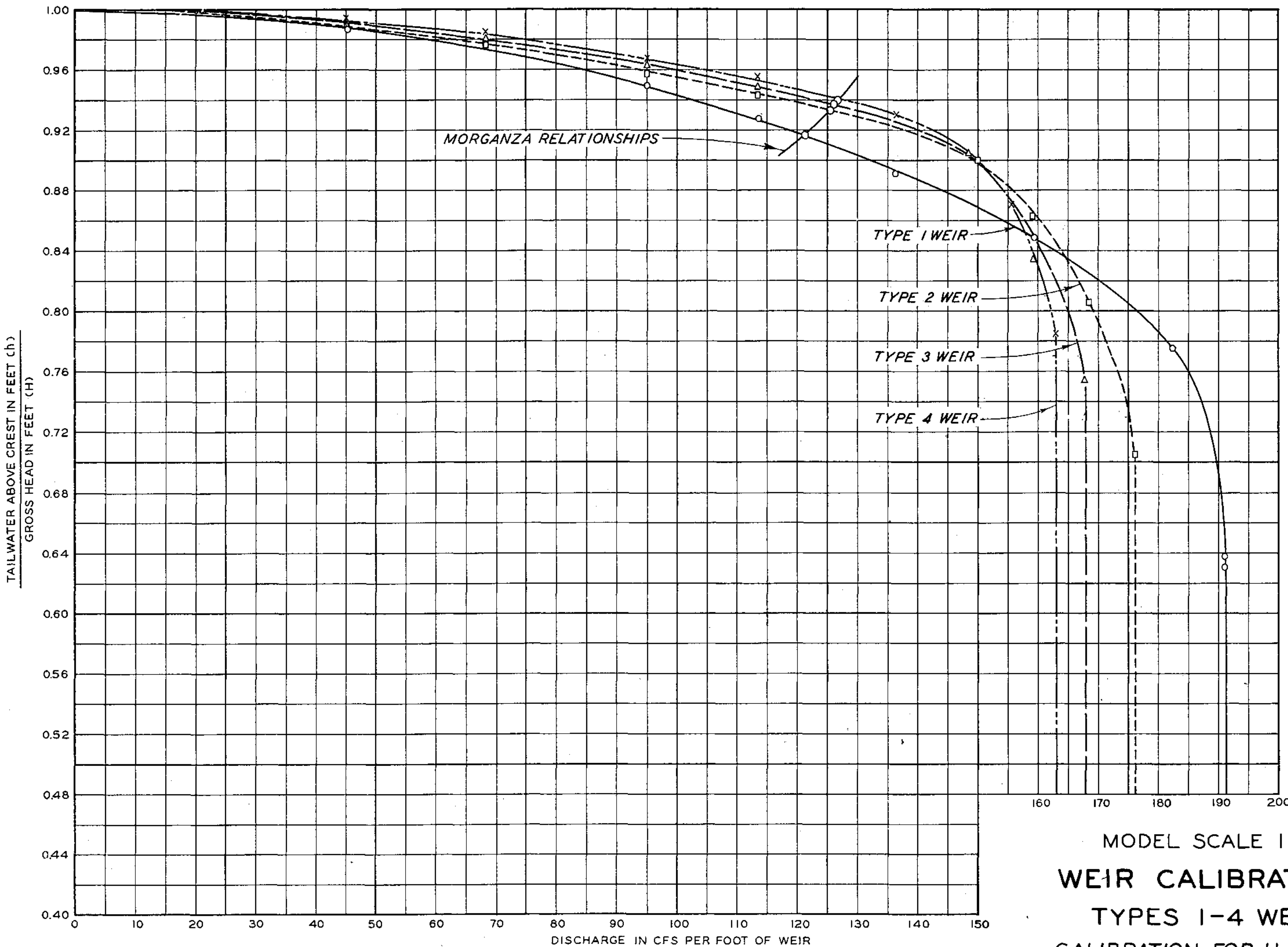


MODEL SCALE 1:30

SUBMERGENCE CURVES

TYPE 4 WEIR

NOTE: DISCHARGE IN CFS PER FOOT OF WEIR



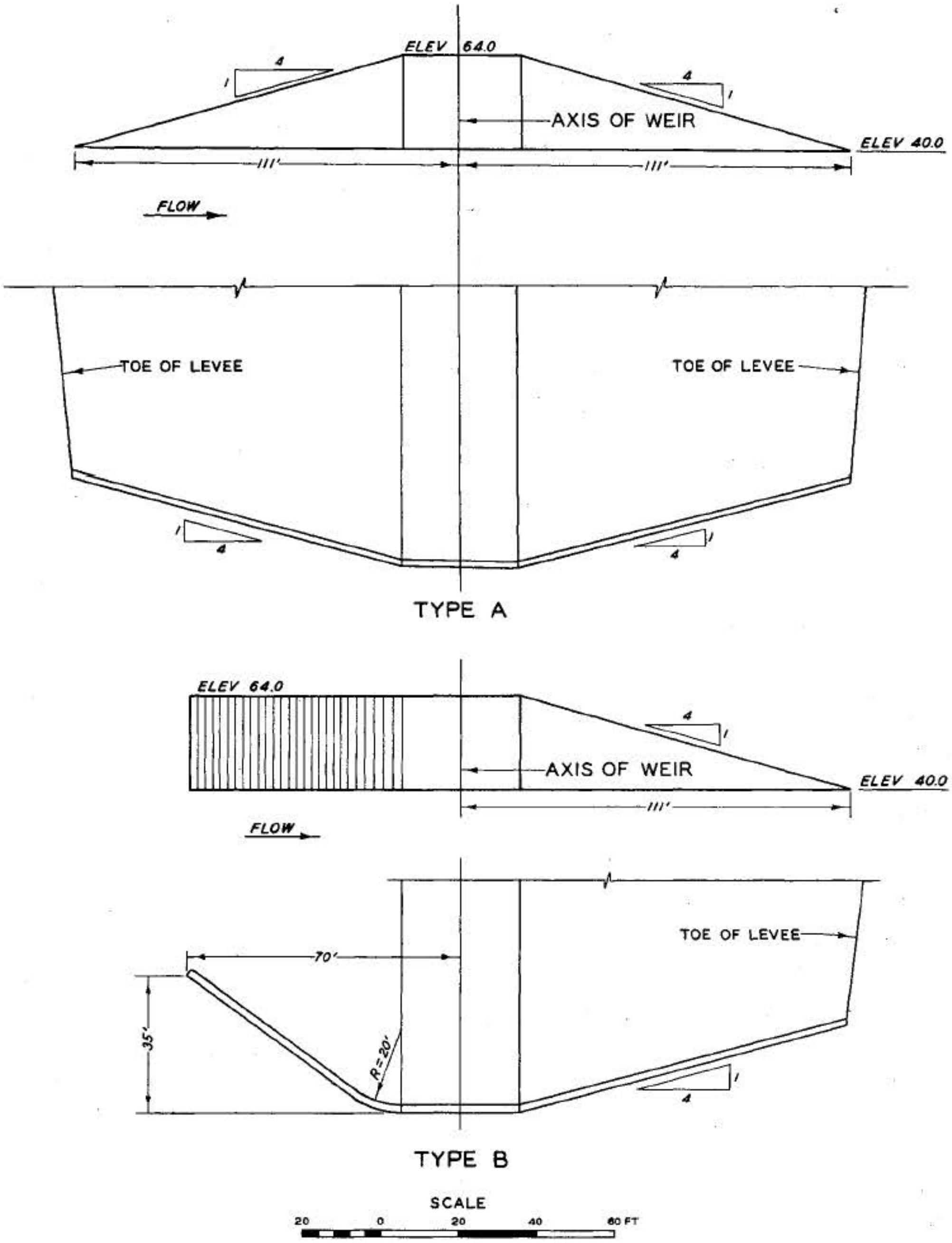
MODEL SCALE 1:30

WEIR CALIBRATIONS

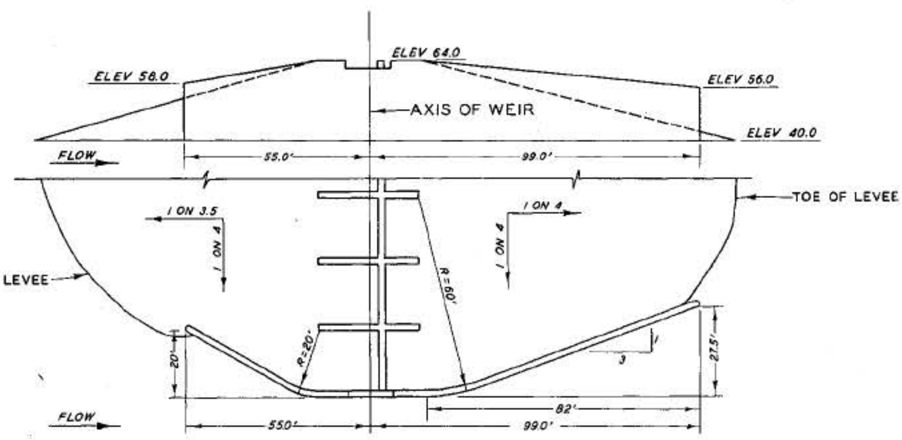
TYPES 1-4 WEIRS

CALIBRATION FOR H = 13.8 FT

PLATE 13



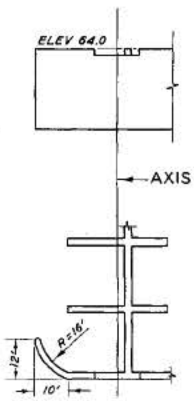
ABUTMENT WALL DESIGNS
TYPES A AND B



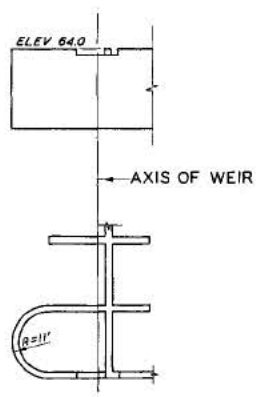
TYPE C

SCALE

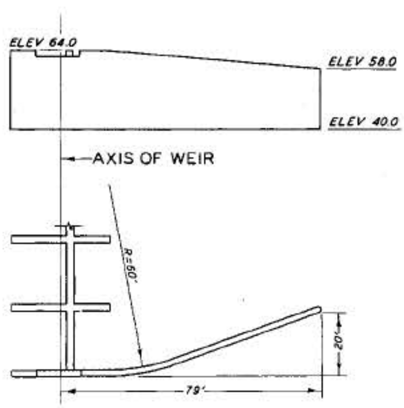
20 0 20 40 60 FT



TYPE C-1



TYPE C-2



TYPE C-3

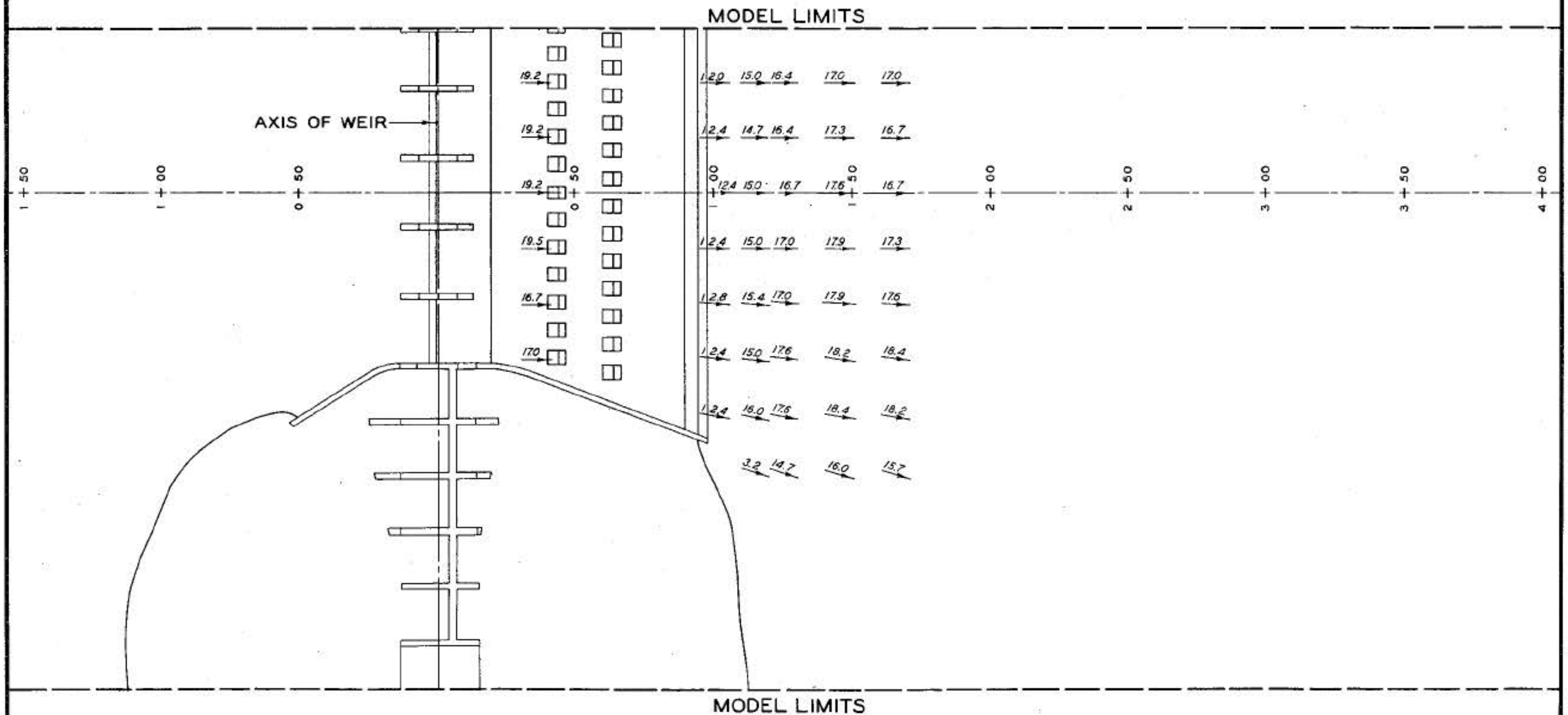
SCALE

20 0 20 40 60 FT

ABUTMENT WALL DESIGNS

TYPE C

PLATE 16



NOTE: VELOCITIES ARE IN FEET PER SECOND PROTOTYPE.
VELOCITIES MEASURED 2 FEET ABOVE BOTTOM.
BED MOLDED WITH CEMENT MORTAR FLAT TO ELEVATION 40.0 MSL.

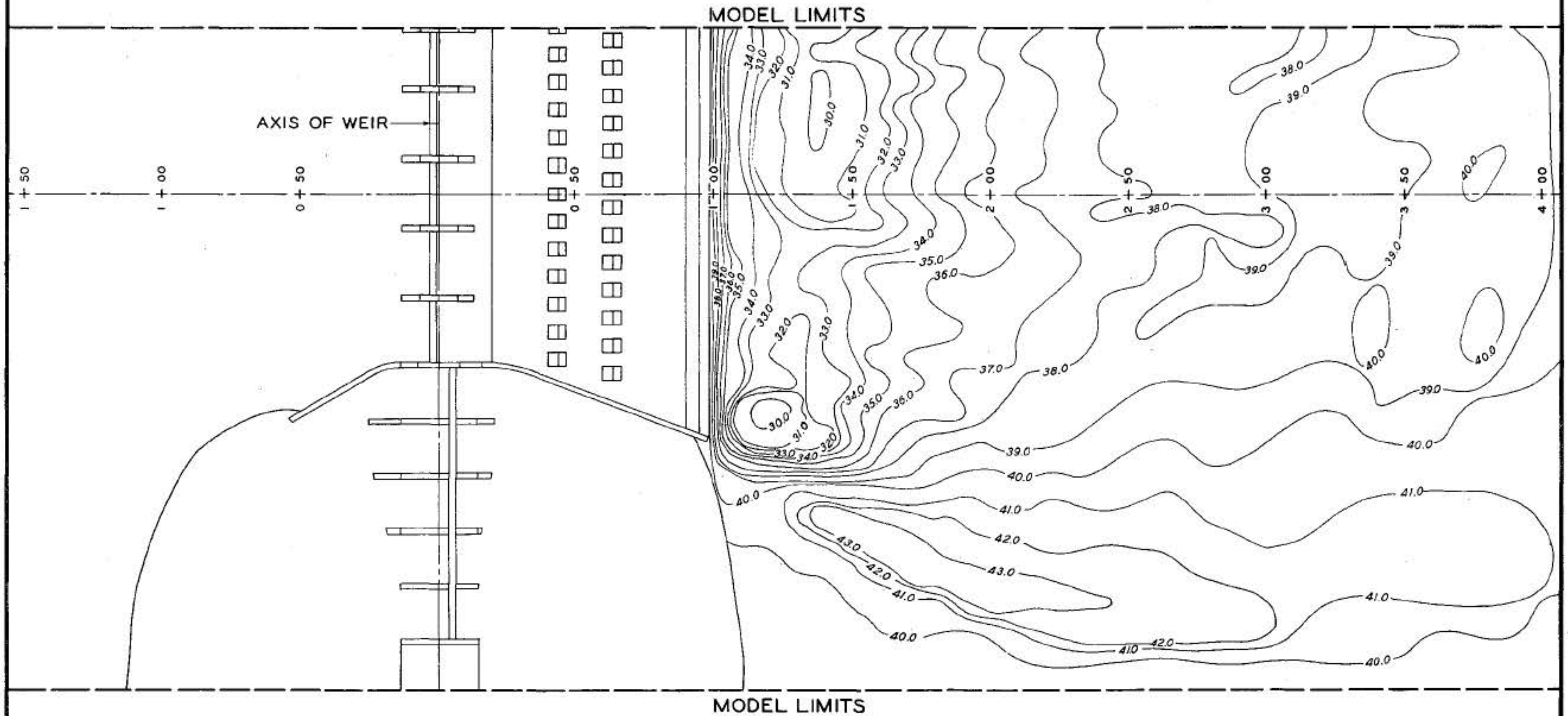
TEST CONDITIONS

DISCHARGE	490,000 CFS
POOL ELEVATION	53.6
TAILWATER ELEVATION	MINIMUM
ROW OF 5.0 FT. BAFFLES STATION	0+39.5
ROW OF 5.0 FT. BAFFLES STATION	0+59.5
5.0 FT. END SILL STATION	0+90.5

MODEL SCALE 1:16

BOTTOM VELOCITIES

TYPE I SPILLWAY DESIGN
TYPE C ABUTMENT WALL
POOL ELEV 53.6 TAILWATER ELEV MINIMUM
BAFFLE PIERS IN PLACE



MODEL SCALE 1:16

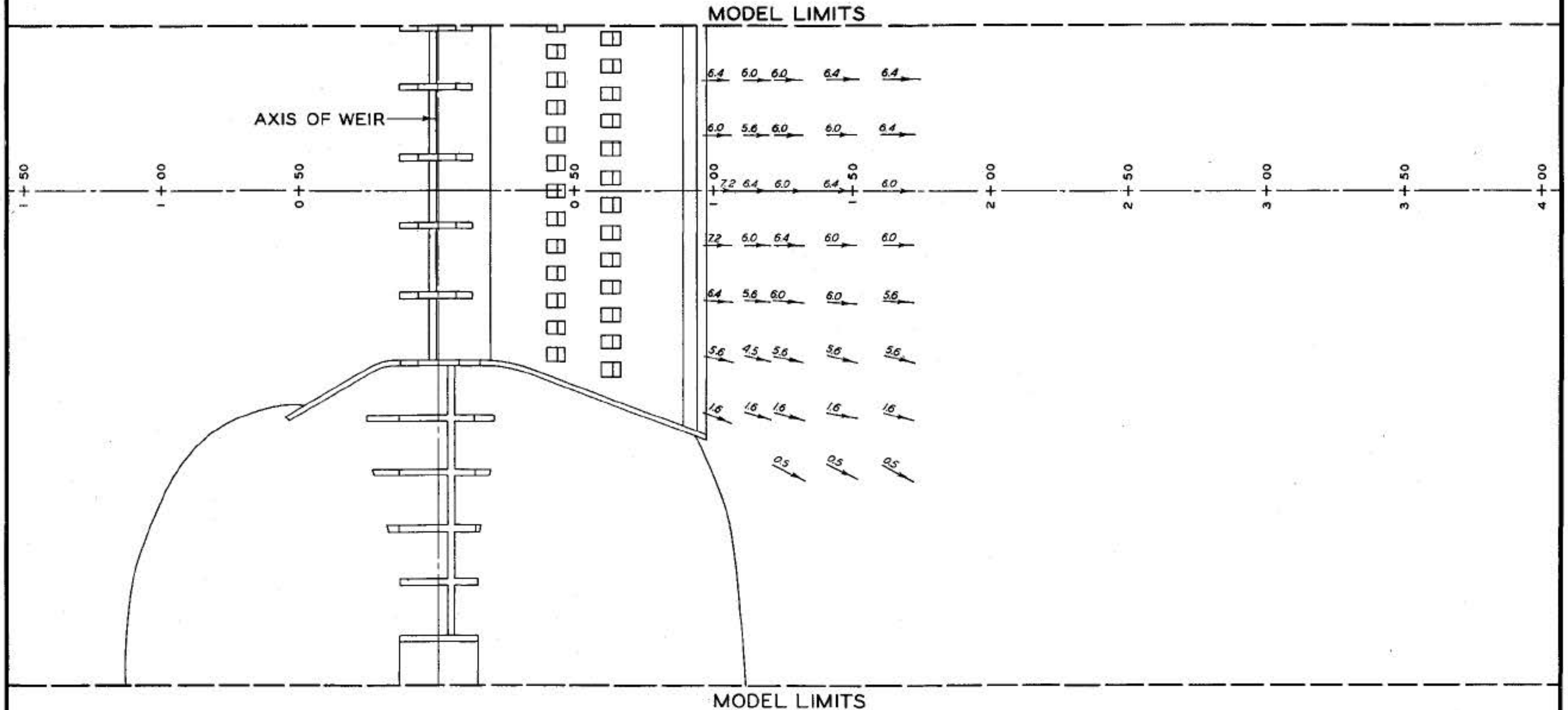
SCOUR PATTERN

TYPE I SPILLWAY DESIGN
TYPE C ABUTMENT WALL
POOL ELEV 53.6 TAILWATER ELEV MINIMUM
BAFFLE PIERS IN PLACE

TEST CONDITIONS

DISCHARGE	490,000 CFS
POOL ELEVATION	53.6
TAILWATER ELEVATION	MINIMUM
ROW OF 5.0 FT. BAFFLES STATION	0+39.5
ROW OF 5.0 FT. BAFFLES STATION	0+59.5
5.0 FT. END SILL STATION	0+90.5

NOTE: STATIONS REFER TO DISTANCE ALONG CENTERLINE FROM AXIS OF DAM. ELEVATIONS ARE IN FEET REFERRED TO MEAN SEA LEVEL. SAND BED MOLDED FLAT TO ELEVATION 40.0



NOTE: VELOCITIES ARE IN FEET PER SECOND PROTOTYPE.
VELOCITIES MEASURED 2 FEET ABOVE BOTTOM.
BED MOLDED WITH CEMENT MORTAR FLAT TO ELEVATION 40.0 MSL

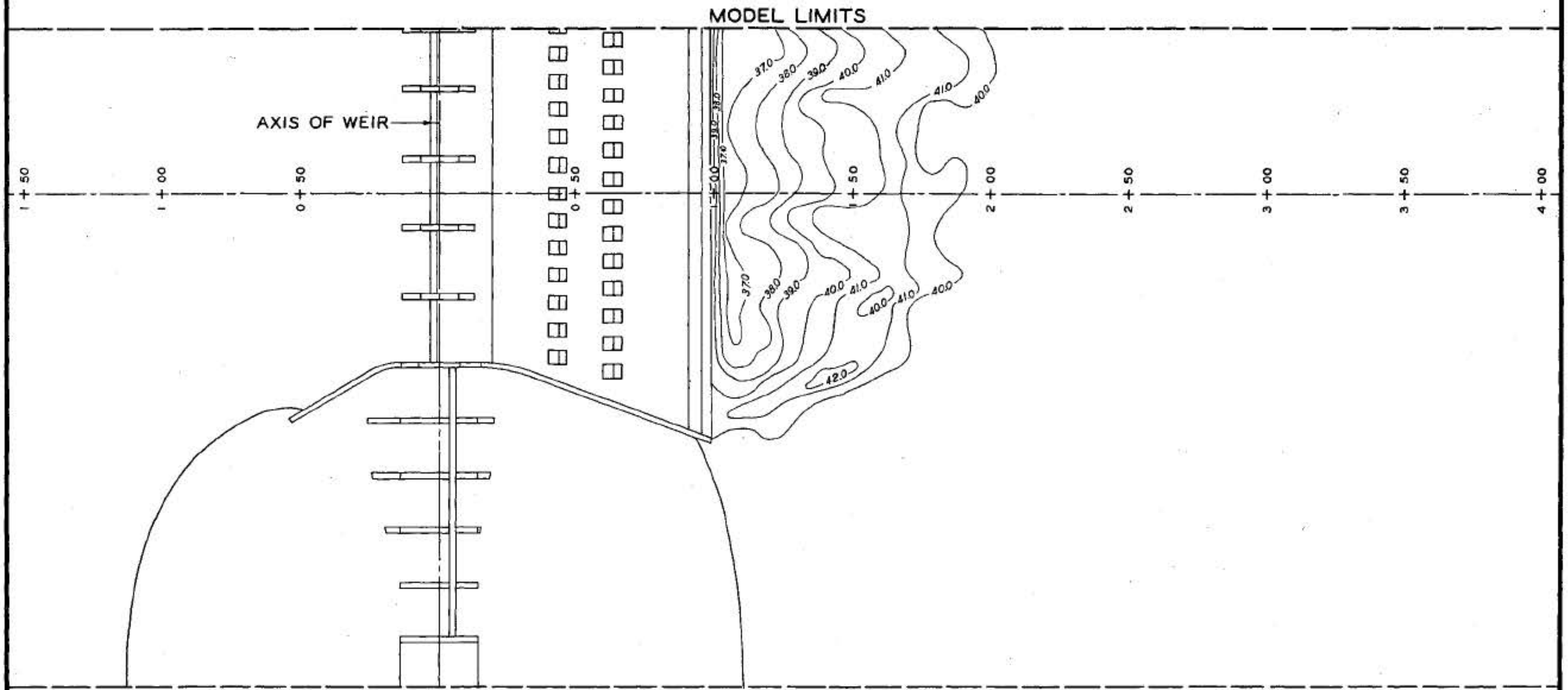
TEST CONDITIONS

DISCHARGE	490,000 CFS
POOL ELEVATION	56.9
TAILWATER ELEVATION	55.7
ROW OF 5.0 FT. BAFFLES STATION	0+39.5
ROW OF 5.0 FT. BAFFLES STATION	0+59.5
5.0 FT END SILL STATION	0+90.5

MODEL SCALE 1:16

BOTTOM VELOCITIES

TYPE I SPILLWAY DESIGN
TYPE C ABUTMENT WALL
POOL ELEV 56.9 TAILWATER ELEV 55.7
BAFFLE PIERS IN PLACE



NOTE: STATIONS REFER TO DISTANCE ALONG CENTERLINE FROM AXIS OF DAM.
ELEVATIONS ARE IN FEET REFERRED TO MEAN SEA LEVEL.
SAND BED MOLDED FLAT TO ELEVATION 40.0

TEST CONDITIONS

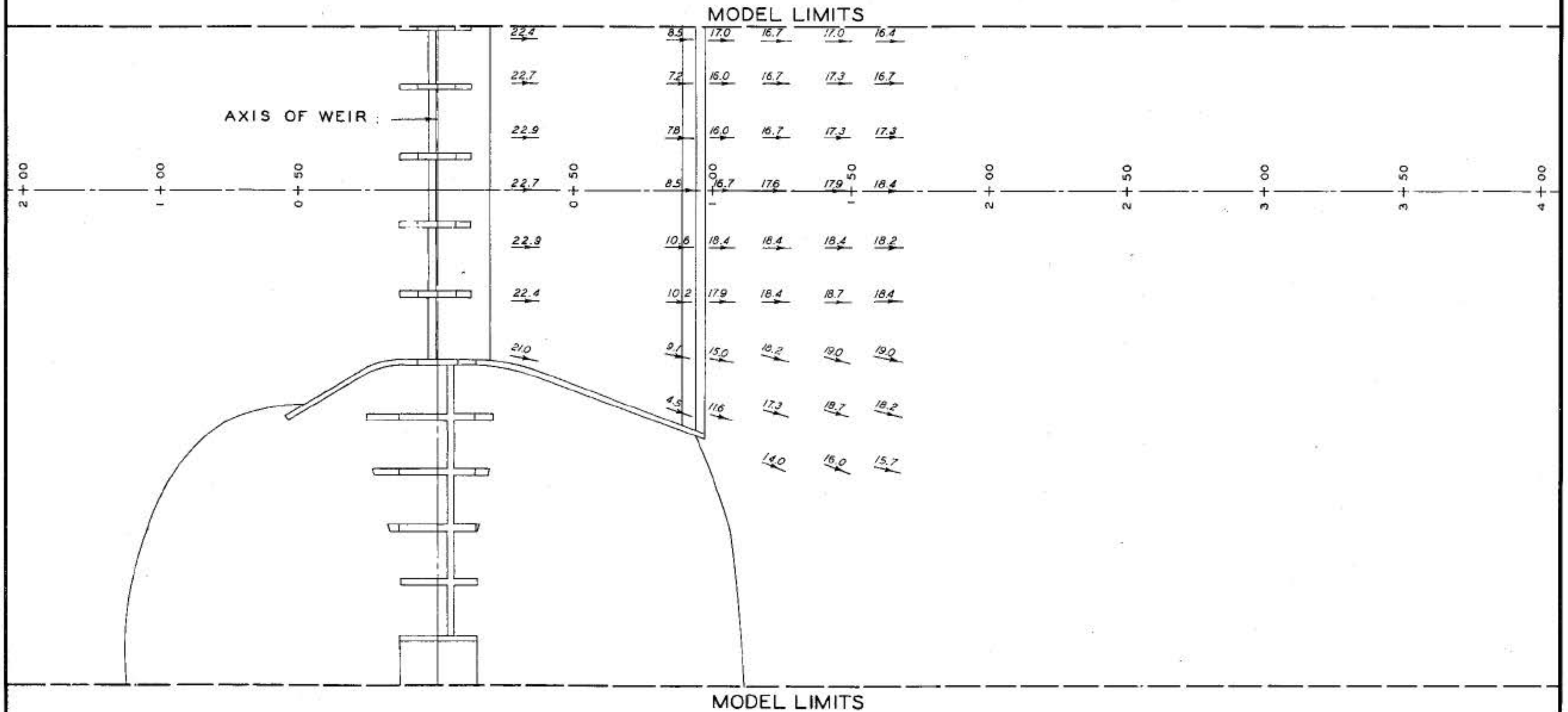
DISCHARGE	490,000 CFS
POOL ELEVATION	56.9
TAILWATER ELEVATION	55.7
ROW OF 5.0 FT. BAFFLES STATION	0+39.5
ROW OF 5.0 FT. BAFFLES STATION	0+59.5
5.0 FT END SILL STATION	0+90.5

MODEL SCALE 1:16

SCOUR PATTERN

TYPE I SPILLWAY DESIGN
TYPE C ABUTMENT WALL
POOL ELEV 56.9 TAILWATER ELEV 55.7
BAFFLE PIERS IN PLACE

PLATE 20



MODEL SCALE 1:16

BOTTOM VELOCITIES

TYPE I SPILLWAY DESIGN

TYPE C ABUTMENT WALL

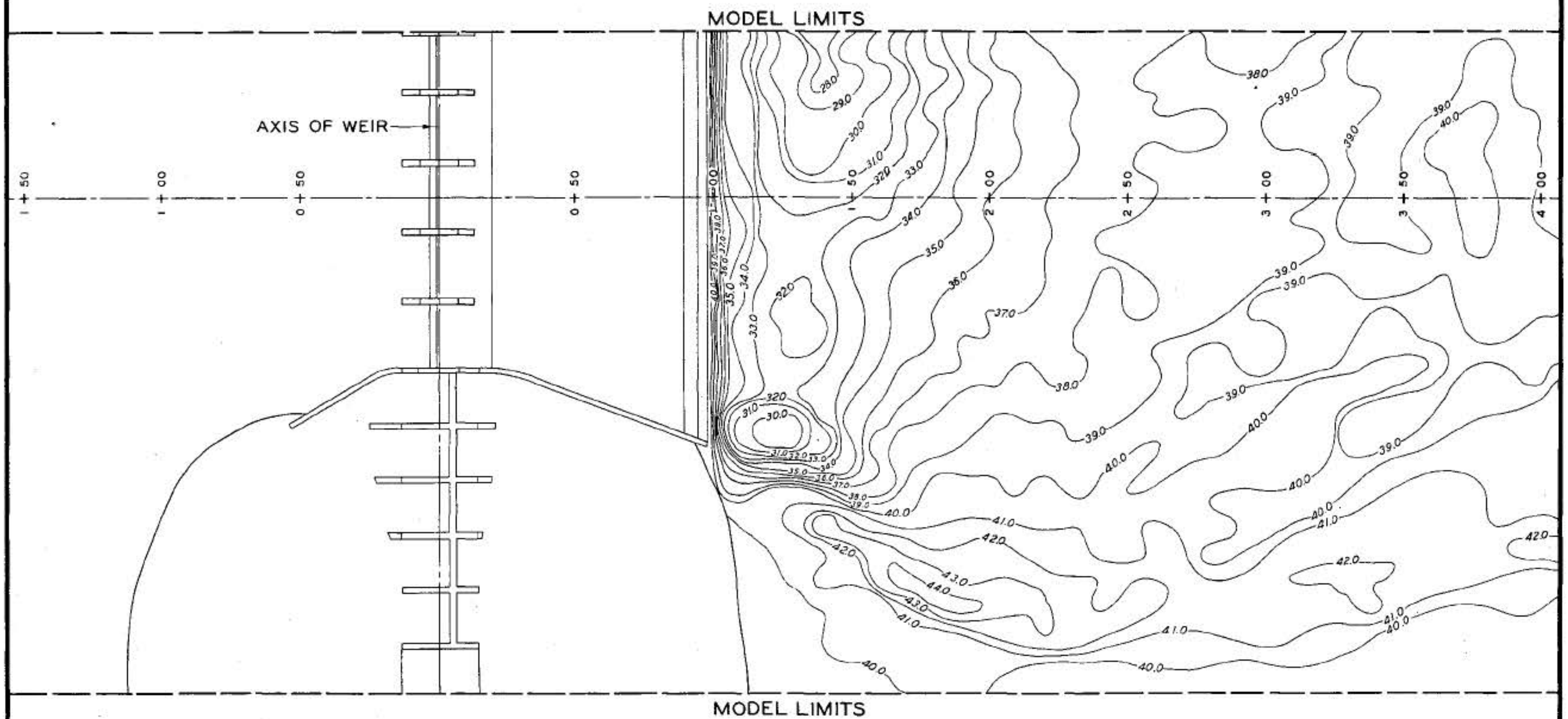
POOL ELEV 53.6 TAILWATER ELEV MINIMUM

NO BAFFLE PIERS

NOTE: VELOCITIES ARE IN FEET PER SECOND PROTOTYPE.
VELOCITIES MEASURED 2 FEET ABOVE BOTTOM.
BED MOLDED WITH CEMENT MORTAR FLAT TO ELEVATION 40.0 MSL

TEST CONDITIONS

DISCHARGE	490,000 CFS
POOL ELEVATION	53.6
TAILWATER ELEVATION	MINIMUM
5.0 FT. END SILL STATION 0+90.5	



MODEL SCALE 1:16

SCOUR PATTERN

TYPE I SPILLWAY DESIGN

TYPE C ABUTMENT WALL

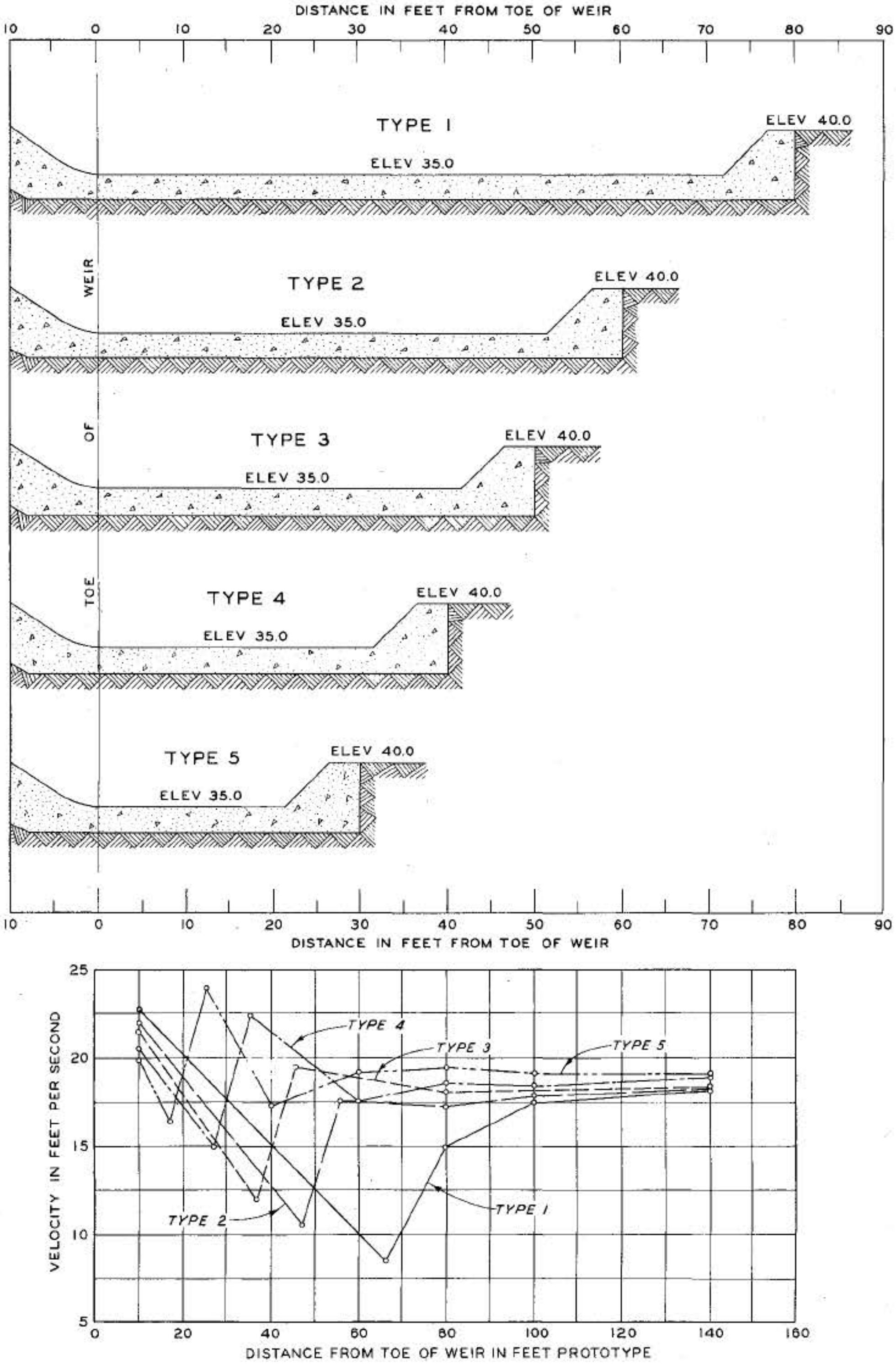
POOL ELEV 53.6 TAILWATER ELEV MINIMUM

NO BAFFLE PIERS

TEST CONDITIONS

DISCHARGE	490,000 CFS
POOL ELEVATION	53.6
TAILWATER ELEVATION	MINIMUM
5.0 FT. END SILL STATION	0 + 90.5

NOTE: STATIONS REFER TO DISTANCE ALONG CENTERLINE FROM AXIS OF DAM.
ELEVATIONS ARE IN FEET REFERRED TO MEAN SEA LEVEL.
SAND BED MOLDED FLAT TO ELEVATION 40.0.



TEST CONDITIONS

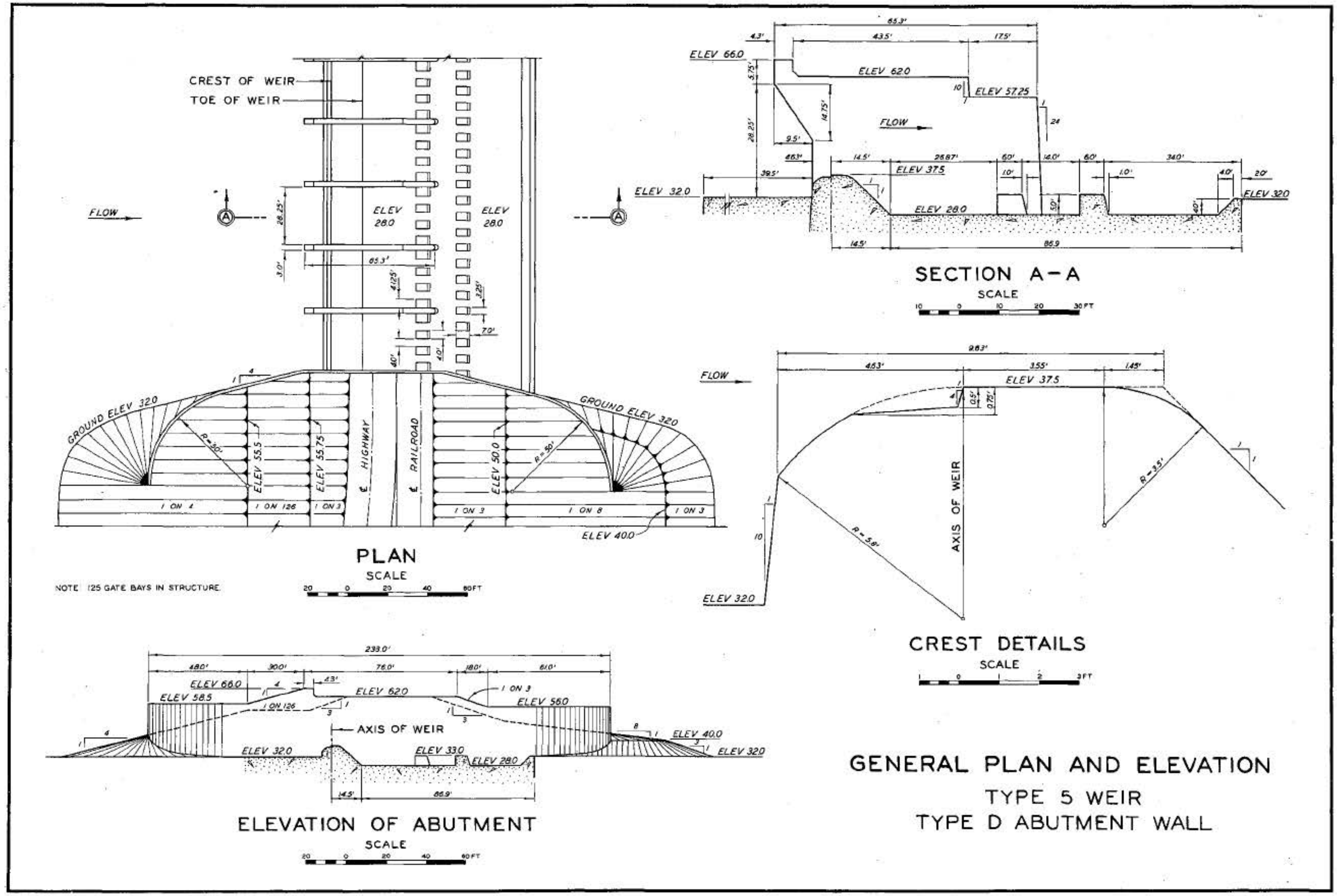
DISCHARGE	490,000 CFS
POOL ELEV	53.6
TAILWATER ELEV	MINIMUM
BAFFLE PIERS REMOVED	

NOTE: VELOCITIES ARE MEASURED 2 FT. ABOVE BOTTOM ALONG CENTERLINE.

MODEL SCALE 1:16

COMPARISON OF STILLING-BASIN LENGTHS

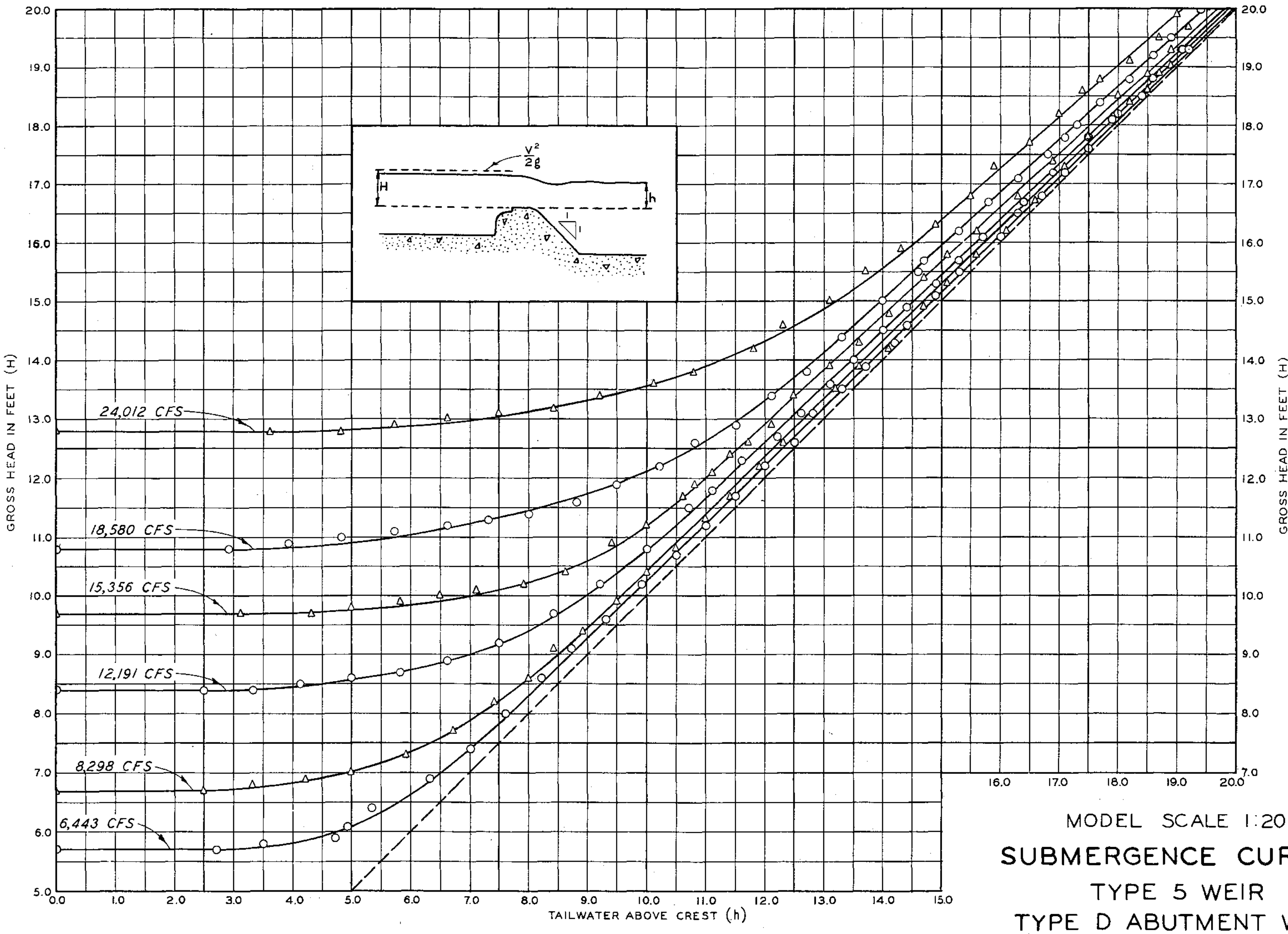
TYPE I SPILLWAY DESIGN
TYPE C ABUTMENT WALL



CREST OF WEIR
TOE OF WEIR
FLOW
ELEV 28.0
ELEV 28.0
GROUND ELEV 32.0
GROUND ELEV 32.0
ELEV 55.5
ELEV 55.75
HIGHWAY
RAILROAD
ELEV 50.0
R=30'
R=50'
1 ON 4
1 ON 126
1 ON 3
1 ON 3
1 ON 8
1 ON 3
ELEV 40.0
PLAN
SCALE
NOTE: 125 GATE BAYS IN STRUCTURE.
SECTION A-A
SCALE
ELEV 66.0
ELEV 62.0
ELEV 57.25
FLOW
ELEV 32.0
ELEV 37.5
ELEV 28.0
ELEV 32.0
CREST DETAILS
SCALE
FLOW
ELEV 37.5
AXIS OF WEIR
R=5.8'
R=3.5'
ELEV 32.0
ELEVATION OF ABUTMENT
SCALE
ELEV 66.0
ELEV 58.5
ELEV 62.0
ELEV 56.0
1 ON 126
1 ON 3
AXIS OF WEIR
ELEV 32.0
ELEV 33.0
ELEV 28.0
ELEV 40.0
ELEV 32.0
GENERAL PLAN AND ELEVATION
TYPE 5 WEIR
TYPE D ABUTMENT WALL

PLATE 23

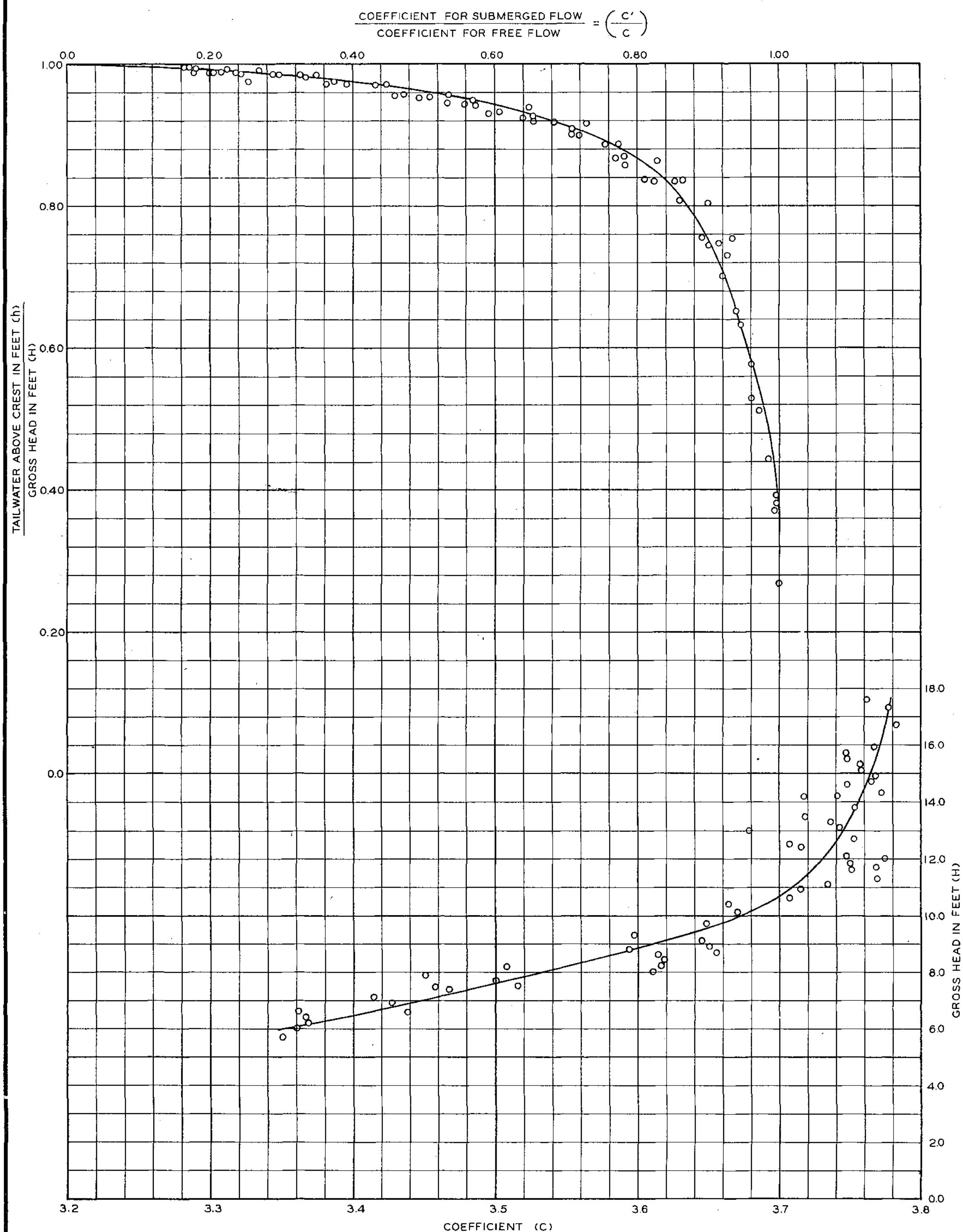
PLATE 24



NOTE: DISCHARGE FOR 5 BAYS.

MODEL SCALE 1:20

SUBMERGENCE CURVES
TYPE 5 WEIR
TYPE D ABUTMENT WALL



COEFFICIENT $C' = \frac{Q}{LH^{\frac{3}{2}}}$

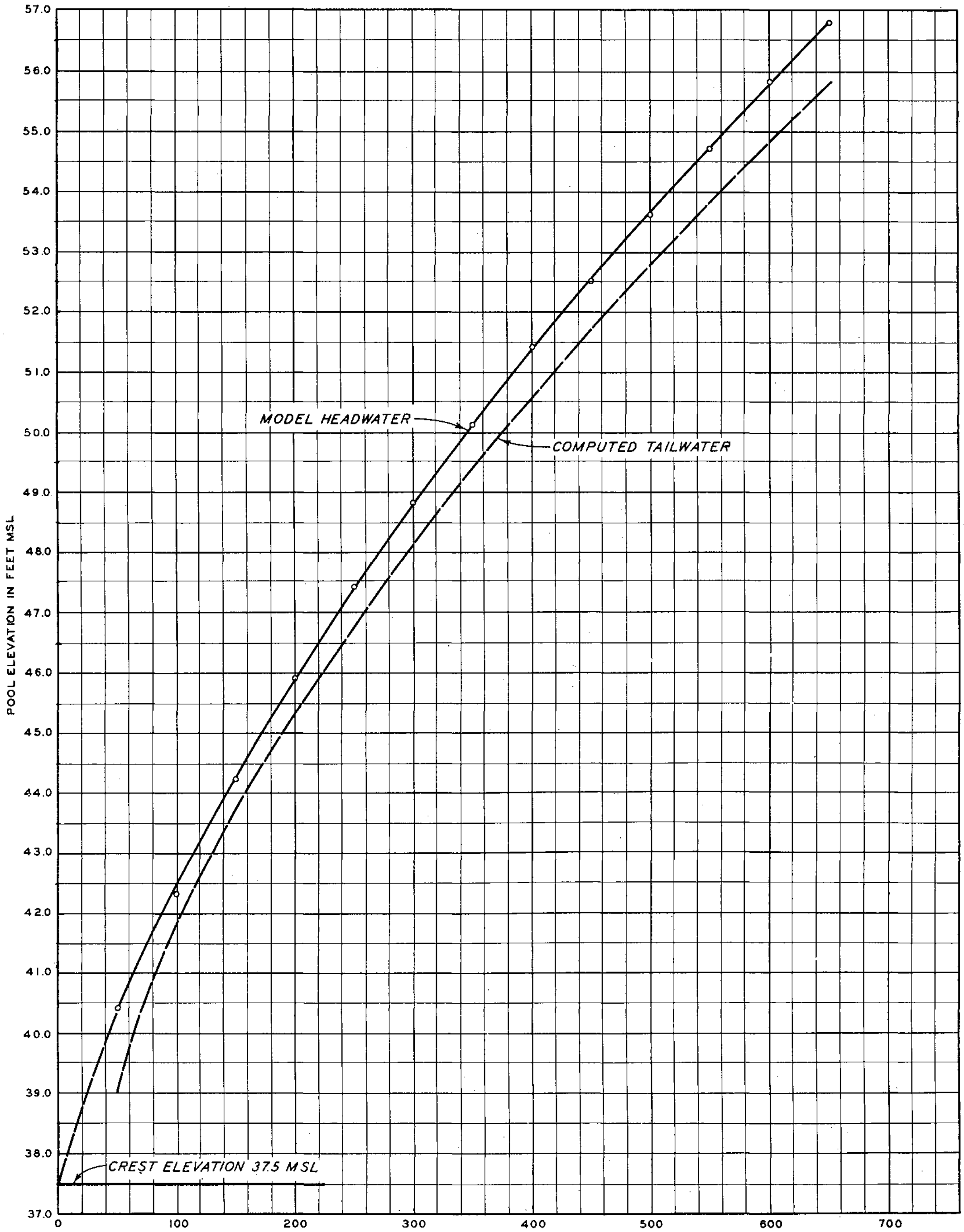
NOTE: PIER CONTRACTION EFFECTS INCLUDED IN COEFFICIENTS C AND C′

MODEL SCALE 1:20

DISCHARGE COEFFICIENTS

TYPE 5 WEIR

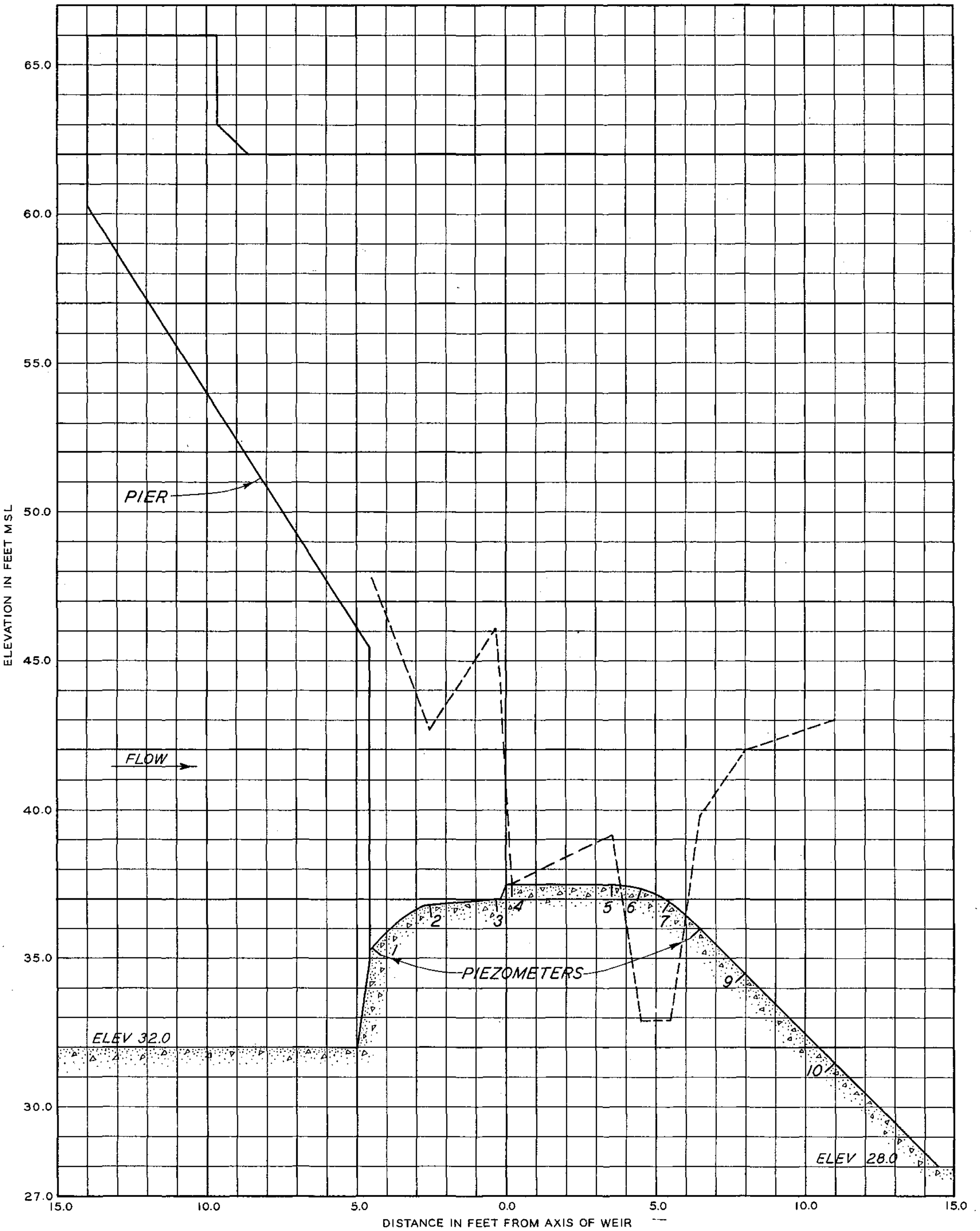
TYPE D ABUTMENT WALL



MODEL SCALE 1:20

HEADWATER - TAILWATER CURVES

TYPE 5 SPILLWAY DESIGN
TYPE D ABUTMENT WALL



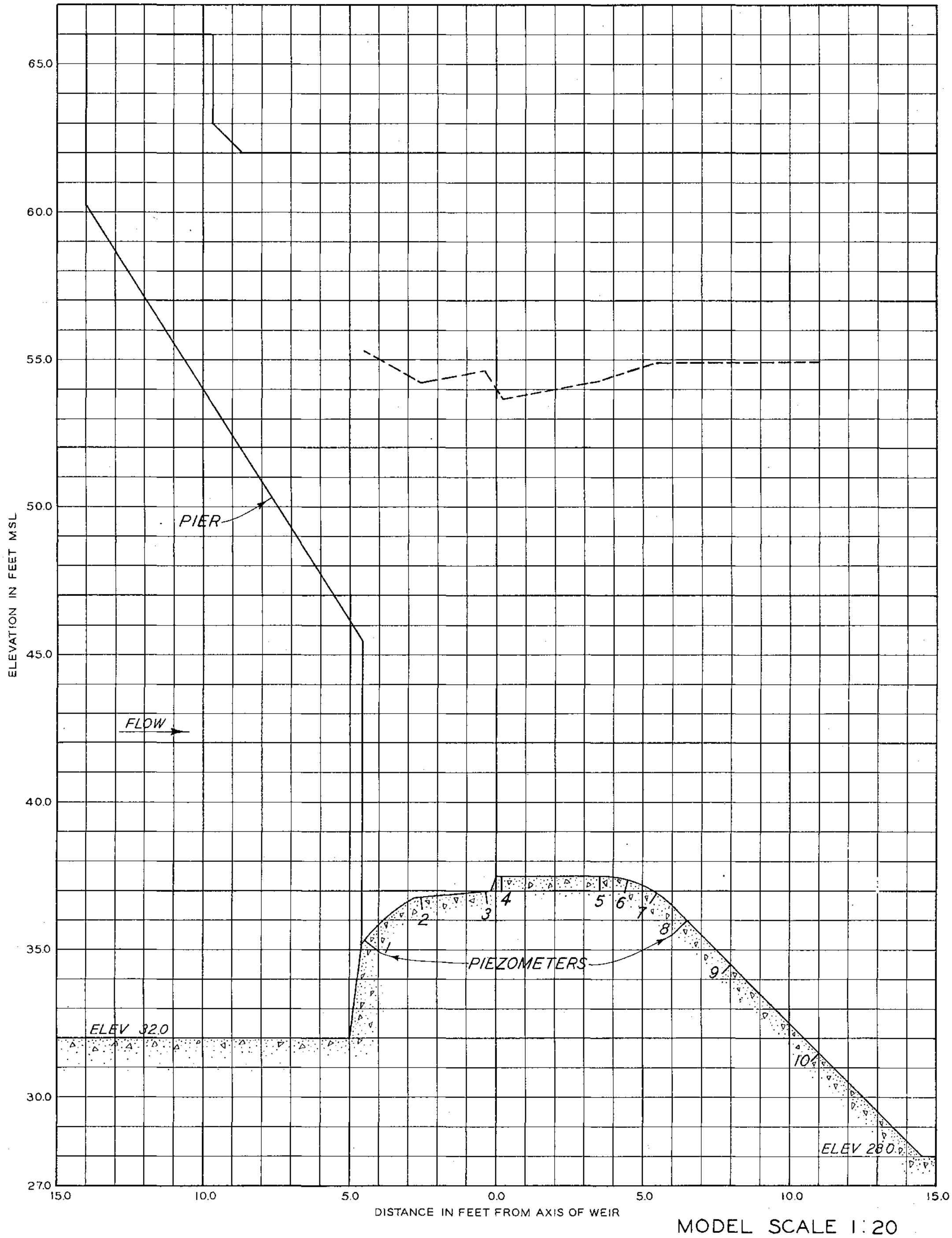
MODEL SCALE 1:20

PRESSURE PROFILE

TYPE 5 WEIR

TYPE D ABUTMENT WALL

DISCHARGE	600,300 CFS
POOL ELEV	50.3
TAILWATER ELEV	MINIMUM



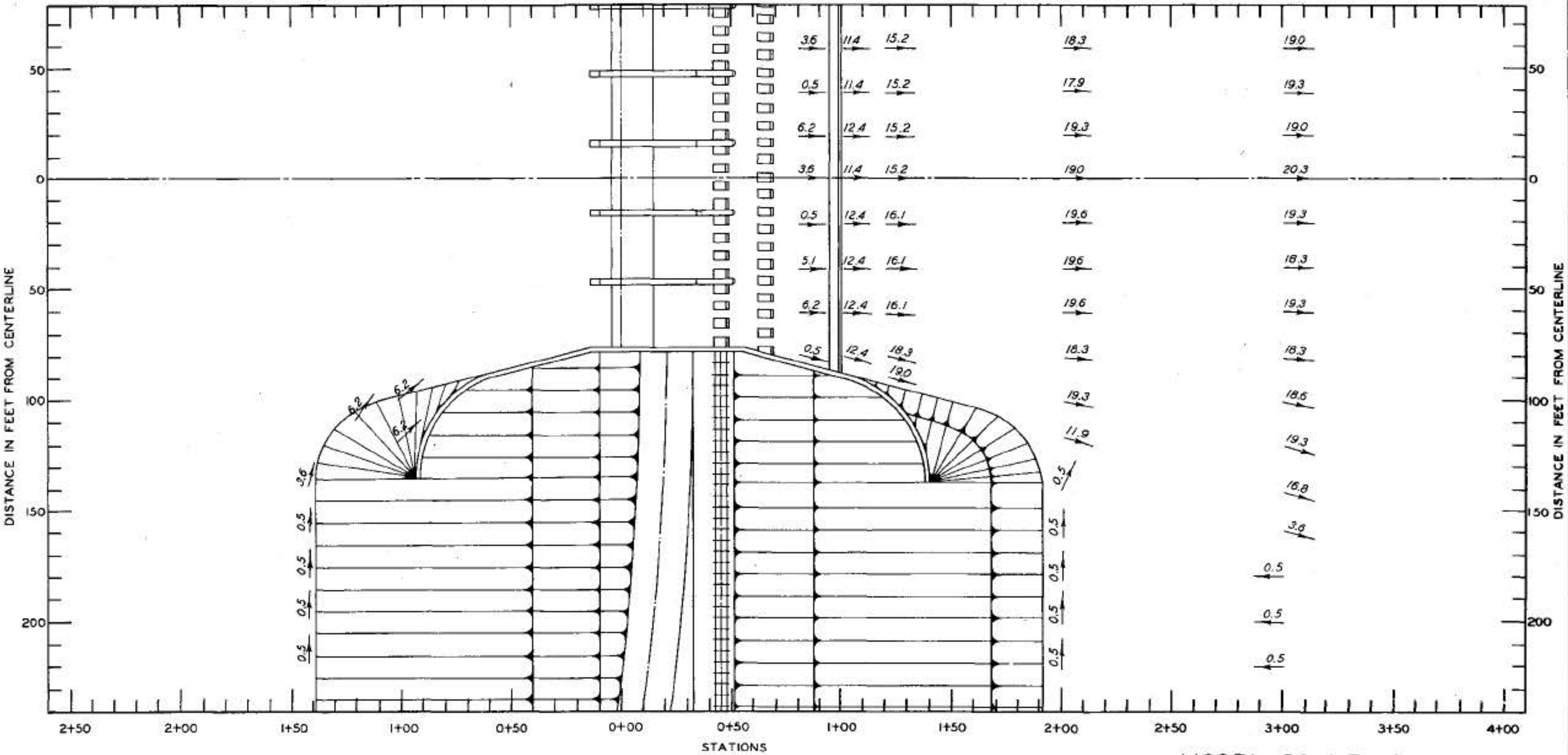
MODEL SCALE 1:20

PRESSURE PROFILE

TYPE 5 WEIR

TYPE D ABUTMENT WALL

DISCHARGE	600,300 CFS
POOL ELEV	55.9
TAILWATER ELEV	54.9



MODEL SCALE 1:20

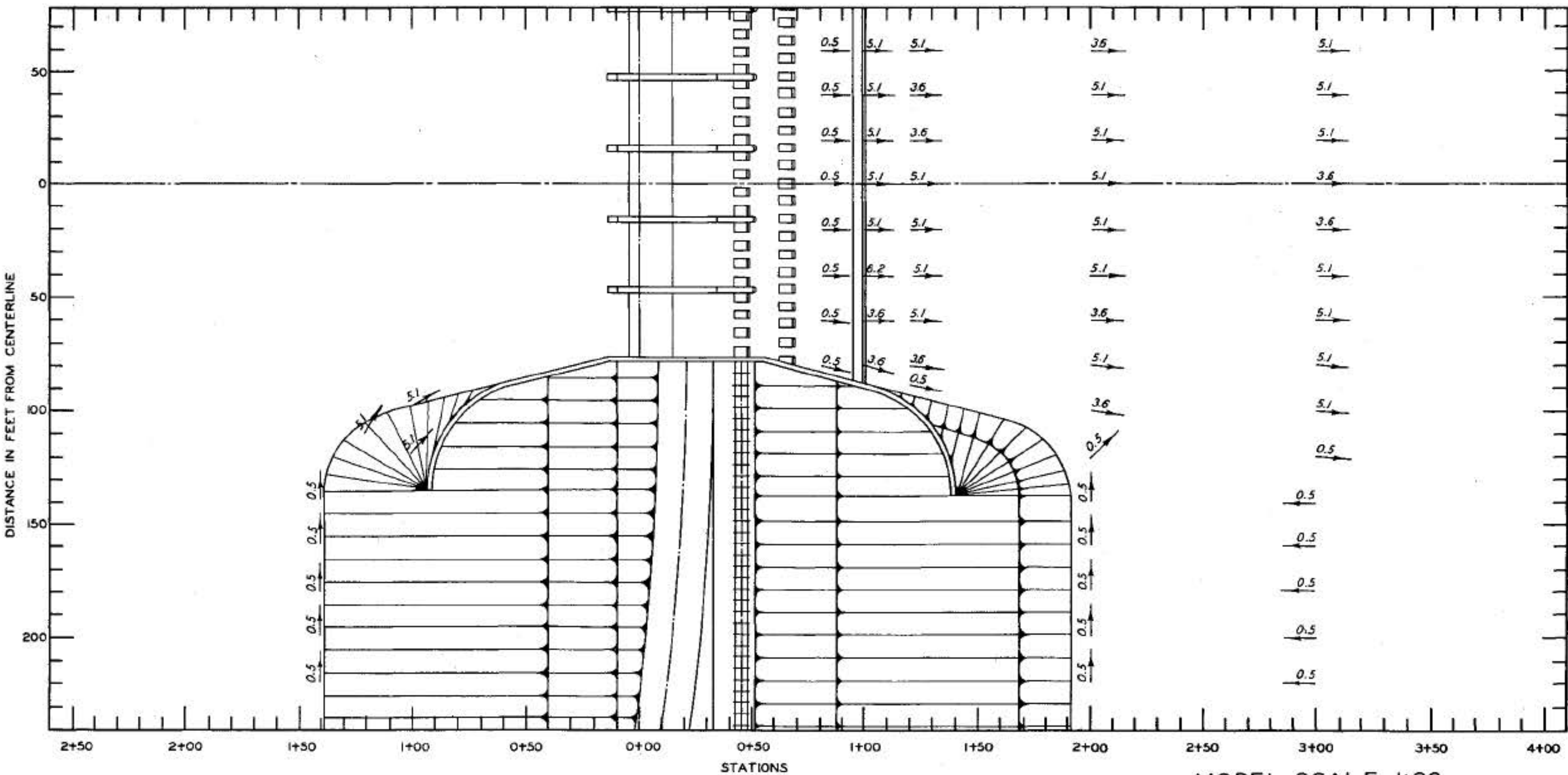
VELOCITIES

TYPE 5 WEIR

TYPE D ABUTMENT WALL

DISCHARGE	400,000 CFS
POOL ELEVATION	47.2
TAILWATER ELEVATION	MINIMUM

NOTE : VELOCITIES ARE IN FEET PER SECOND PROTOTYPE.
VELOCITIES MEASURED 2 FEET ABOVE BOTTOM.
BED MOLDED WITH CEMENT MORTAR FLAT TO ELEVATION 32.0 MSL



MODEL SCALE 1:20

VELOCITIES

TYPE 5 WEIR

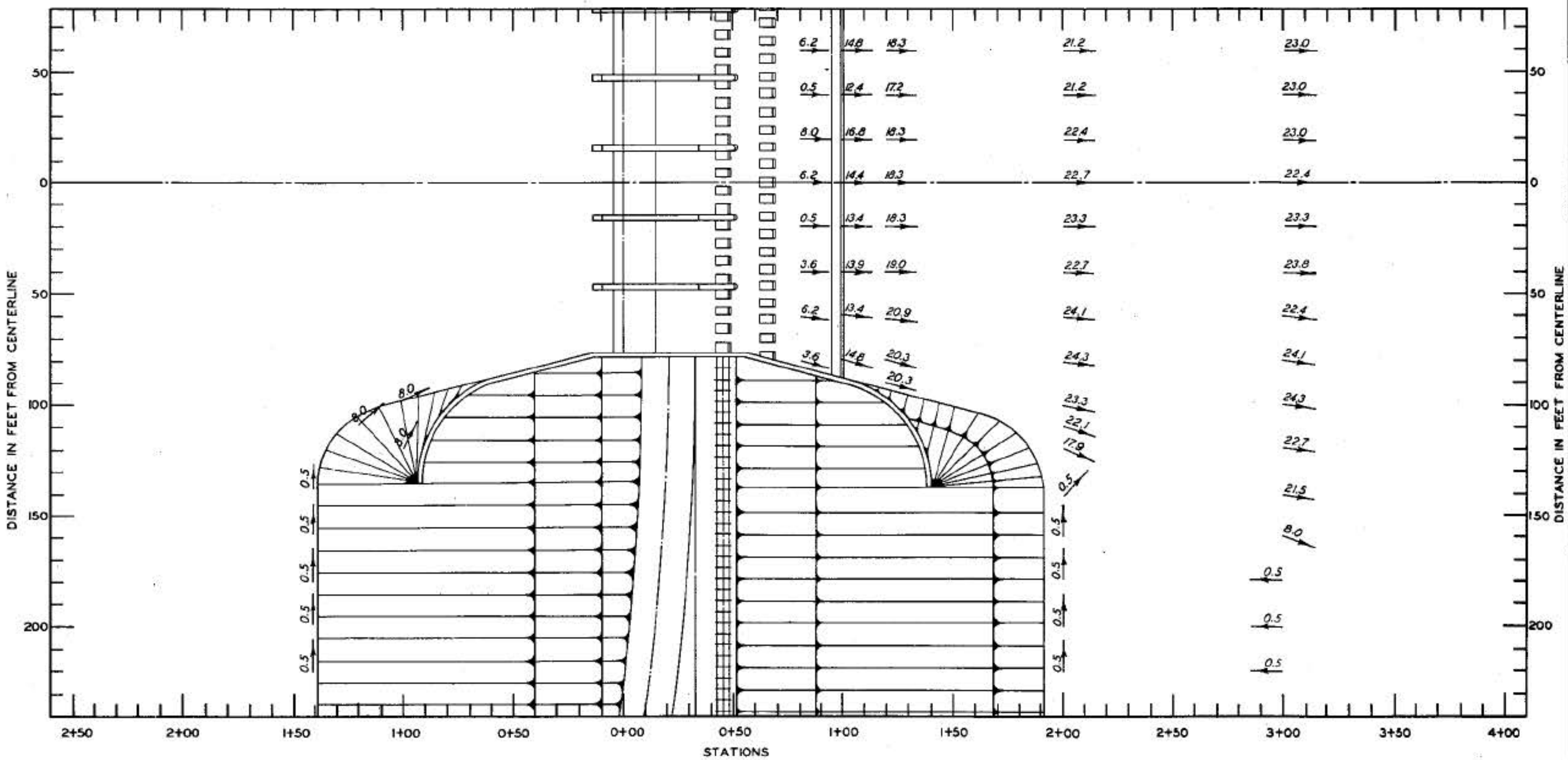
TYPE D ABUTMENT WALL

DISCHARGE 400,000 CFS

POOL ELEVATION 51.4

TAILWATER ELEVATION 50.6

NOTE : VELOCITIES ARE IN FEET PER SECOND PROTOTYPE.
VELOCITIES MEASURED 2 FEET ABOVE BOTTOM.
BED MOLDED WITH CEMENT MORTAR FLAT TO ELEVATION 32.0 MSL.



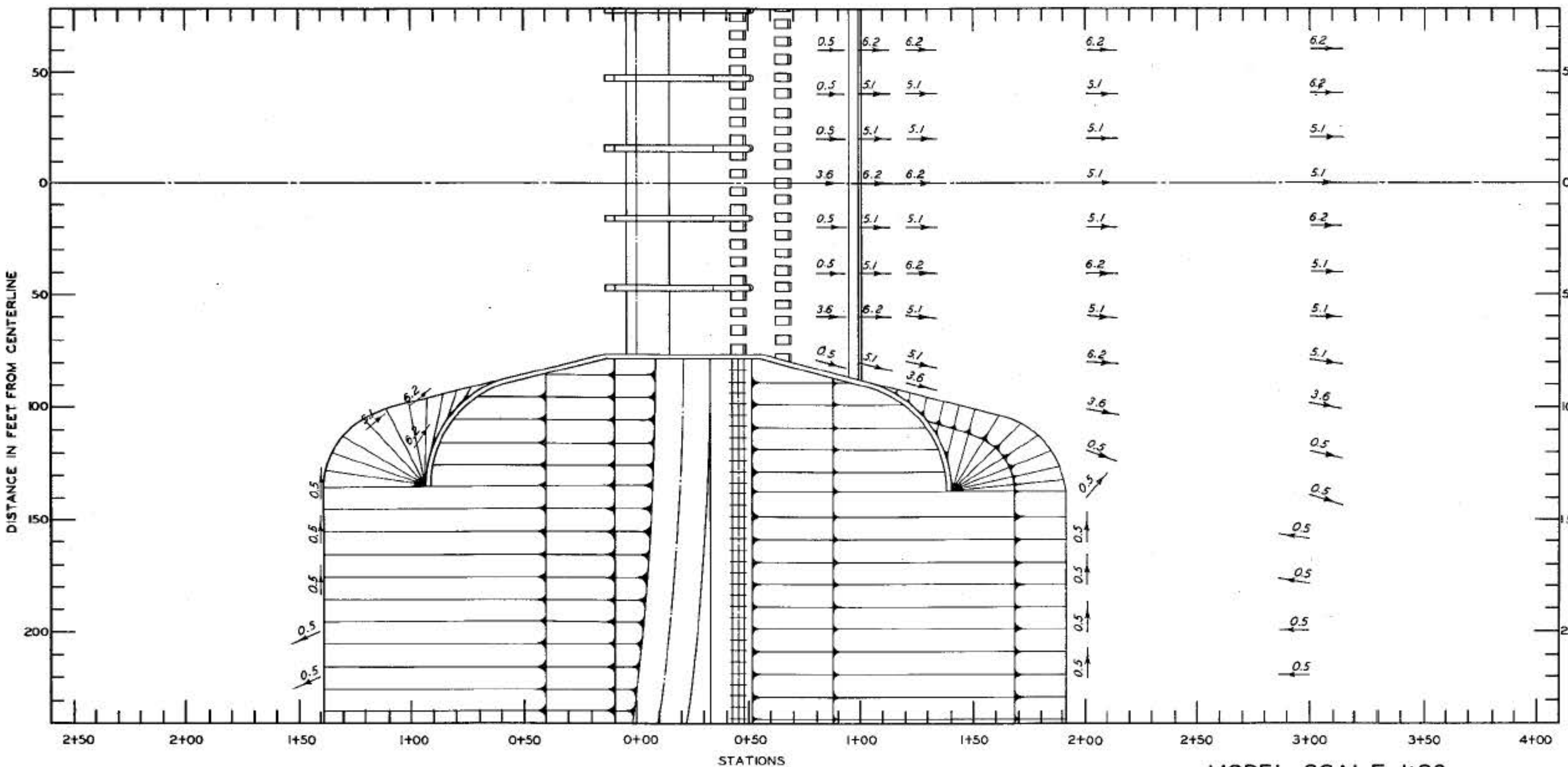
MODEL SCALE 1:20

VELOCITIES

TYPE 5 WEIR
TYPE D ABUTMENT WALL

DISCHARGE	650,000 CFS
POOL ELEVATION	50.6
TAILWATER ELEVATION	MINIMUM

NOTE : VELOCITIES ARE IN FEET PER SECOND PROTOTYPE.
VELOCITIES MEASURED 2 FEET ABOVE BOTTOM.
BED MOLDED WITH CEMENT MORTAR FLAT TO ELEVATION 32.0 MSL



MODEL SCALE 1:20

VELOCITIES

TYPE 5 WEIR

TYPE D ABUTMENT WALL

DISCHARGE	650,000 CFS
POOL ELEVATION	56.8
TAILWATER ELEVATION	55.8

NOTE : VELOCITIES ARE IN FEET PER SECOND PROTOTYPE.
VELOCITIES MEASURED 2 FEET ABOVE BOTTOM.
BED MOLDED WITH CEMENT MORTAR FLAT TO ELEVATION 32.0 MSL